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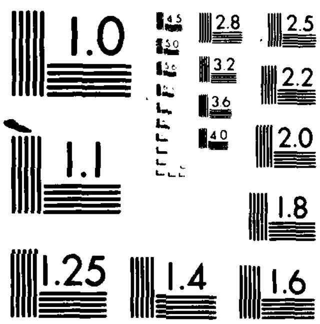

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TEST OF THE APPLICATION OF THE TYWAVES MODEL TO PREDICTION OF SWELL IN THE EAST CHINA SEA FROM THREE TROPICAL CYCLONES IN THE WESTERN NORTH PACIFIC.

by

(10) ~~Lee,~~ Hyong Sun/Lee

(11) Dec[redacted]80

Thesis Advisor: J. B. Wickham

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A method for predicting swell from tropical cyclones using a spectral wave model (TYWAVES) was tested. The model was applied to predicting swell propagating from three typhoons in the Western North Pacific through gaps in the Ryukyu Islands into a region of the East China Sea. The model involves a source region concept which considers only the swell emanating from regions of peak energy in moving typhoons. For three representative typhoons predicted heights were not significantly different from the

Next page

observed heights. The time of occurrence of the predicted peak height agreed well with observational values for the swell from two typhoons, but lagged by 6-12 hours for the third.

The dominant swell period and direction predicted by the model were not verifiable by data available for this study.

Shoaling and refraction effects were considered in the prediction, in a simplified way, but attenuation was ignored even for the passage of energy through the Ryukyu Islands.

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Test of the Application of the TYWAVES
Model to Prediction of Swell in the East
China Sea from Three Topical Cyclones in
the Western North Pacific

by

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Lieutenant Commander, Republic of Korea Navy
B.S., Republic of Korea Naval Academy, 1972

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

A method for predicting swell from tropical cyclones using a spectral wave model (TYWAVES) was tested. The model was applied to predicting swell propagating from three typhoons in the Western North Pacific through gaps in the Ryukyu Islands into a region of the East China Sea. The model involves a source region concept which considers only the swell emanating from regions of peak energy in moving typhoons. For three representative typhoons, predicted heights were not significantly different from the observed heights. The time of occurrence of the predicted peak height agreed well with observational values for the swell from two typhoons, but lagged by 6-12 hours for the third.

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ACKNOWLEDGMENTS

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I. INTRODUCTION

A. OBJECTIVE OF THE STUDY

A serious problem for naval activities, ocean industry, shore protection and fisheries in the Korean south coastal area is the lack of adequate estimation of the waves resulting from typhoons. The objective of this study is to make a partial test of the TYWAVES for forecasting swell from tropical cyclones which arrive at a single observation site near Cheju-do, Korea (33.2°N 126.6°E).

Forecasting based on wave fields predicted in a typhoon area by the TYWAVES [13] developed by NEPRF (Naval Environmental Prediction Research Facility) are to be verified against swell observations made near Cheju-do.

B. TYPHOONS IN THE WESTERN NORTH PACIFIC

During 1979, the Western North Pacific experienced 28 tropical cyclones. Table I, from "1979 Annual Typhoon Report" [2], shows the significant tropical cyclones for that year. Table II from [2] shows the monthly distribution of tropical cyclones in 1979 and other statistics.

Most typhoons occur in the summer season and their tracks can be classified as one of three typical tracks. The first type is that passing south of Taiwan toward the west, the second is that crossing over Korea through the

Ryukyu Islands, and the third is that passing east of Ryukyu Islands.

I selected one typhoon of each type; one each in July, August, and September in 1979. They are Typhoons Hope, Irving and Owen shown in Figures 1, 2, 3 and 4 from [2]. tropical cyclone "best track" information is shown in Tables III, IV, and V for Typhoon Hope, Irving and Owen, respectively.

C. TYWAVES MODEL (THE TYPHOON WAVES PROGRAM)

The SOWM (Spectral Ocean Wave Model) run at FNOC (Fleet Numerical Oceanography Center) utilizes a coarse operating grid system (100~190NM) which does not allow sufficient resolution to describe adequately the resultant sea state in typhoon areas. Thus, TYWAVES, an improved model for typhoons with a locally finer grid, was developed by NEPRF. FNOC judged that TYWAVES is worthy of evaluation as a possible operational typhoon sea state model [14].

The TYWAVES is intended to produce fields of significant wave height and spectral wave properties on a mesh size consistent with the scales of tropical cyclones and is designed, primarily, for the application to the western North Pacific.

The detailed outputs of TYWAVES are in the form of fields, at each of 12 points, of spectral energy

components, significant wave heights, maximum wave periods, and the predominant wave directions, for 00, 12, 24, 48 and 72 hours, where 00 hours is the time of the first typhoon warning issued. An example of those outputs for Typhoon Owen is shown in Appendix A.

Using these spectral energy components at selected source points, I was able to make predictions based on the propagation of these components as swell into the region, south of Cheju-do, Korea (see Map I, page 21). More details of TYWAVES are described in Ref. 11.

D. FORECASTING AND VERIFICATION

Extremely high sea states are known to be generated in the quadrant to the right of the direction of movement of typhoons. The wave generation in that quadrant of the typhoon derived in TYWAVES from a spectral model utilizing the Pierson-Moskowitz (1964) spectrum. The model describes the spectroangular components of the waves present at a number of grid points in the region of strong winds. Each spectral component of interest is then permitted to propagate at its appropriate group velocity to the forecast site. The method is applied to three western North Pacific typhoons in 1979 and the forecast products are compared with the observed swell data from the south coastal area of Cheju-do, Korea.

TABLE 1. WESTERN NORTH PACIFIC

1979 SIGNIFICANT TROPICAL CYCLONES

CYCLONE	TYPE	NAME	PERIOD OF WARNING	CALENDAR DAYS OF WARNING	MAX SFC WIND	MIN OBS SLP	NUMBER OF WARNINGS	DISTANCE TRAVELLED
01	TY	ALICE	01 JAN-14 JAN	14	110	930	51	2597
02	TY	BESS	20 MAR-25 MAR	6	90	958	21	1804
03	TY	CECIL	11 APR-20 APR	10	80	965	40	2535
04	TS	DOT	10 MAY-16 MAY	7	40	984	24	2876
05	TD	TD-05	23 MAY-24 MAY	2	30	998	6	2170
06	TY	ELLIS	01 JUL-06 JUL	6	85	955	22	1612
07	TS	FAYE	01 JUL-06 JUL	6	40	998	20	1837
08	TD	TD-08	24 JUL-25 JUL	2	20	1004	5	1264
09	ST	HOPE	27 JUL-03 AUG	10	130	898	33	3928
10	TS	GORDON	26 JUL-29 JUL	4	60	980	13	1058
11	TD	TD-11	03 AUG-06 AUG	4	25	997	14	1088
12	TY	IRVING	09 AUG-18 AUG	10	90	954	38	2732
13	ST	JUDY	16 AUG-26 AUG	11	135	887	39	2502
14	TD	TD-14	18 AUG-20 AUG	3	20	1006	9	605
15	TS	KEN	01 SEP-04 SEP	5	60	985	13	1418
16	TY	LOLA	02 SEP-08 SEP	7	90	950	23	1298
17	TY	MAC	15 SEP-24 SEP	10	70	984	35	1831
18	TS	NANCY	19 SEP-22 SEP	4	45	993	14	528
19	TY	OWEN	22 SEP-01 OCT	10	110	918	37	2151
20	TS	PAMELA	25 SEP-26 SEP	3	45	1002	6	984
21	TS	ROGER	03 OCT-07 OCT	6	45	985	16	1920
22	TY	SARAH	04 OCT-15 OCT	12	110	929	43	1194
23	ST	TIP	05 OCT-19 OCT	16	165	870	60	3972
24	ST	VERA	02 NOV-07 NOV	6	140	915	23	1868
25	TS	WAYNE	08 NOV-13 NOV	6	50	990	22	1559
26	TD	TD-26	01 DEC-02 DEC	2	30	998	6	1070
27	TY	ABBY	01 DEC-14 DEC	14	110	951	52	4044
28	TS	BEN	21 DEC-23 DEC	3	60	990	10	2245
			1979 TOTALS	149*			695	

*OVERLAPPING DAYS INCLUDED ONLY ONCE IN SUM.

TABLE 2.

1979 SIGNIFICANT TROPICAL CYCLONE STATISTICS

WESTERN NORTH PACIFIC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	(1959-78) AVERAGE
TROPICAL DEPRESSIONS	0	0	0	0	1	0	1	2	0	0	0	1	5	4.8
TROPICAL STORMS	0	0	0	0	1	0	2	0	4	1	1	1	10	10.0
TYPHOONS	1	0	1	1	0	0	2	2	2	2	1	1	13	18.0
ALL CYCLONES	1	0	1	1	2	0	5	4	6	3	2	3	28	32.8
(1959-78) AVERAGE	0.6	0.4	0.6	0.9	1.4	2.1	5.2	6.8	6.0	4.8	2.7	1.3	32.8	

FORMATION ALERTS

23 of the 27 (85%) Formation Alert Events developed into tropical cyclones.

5 of the 28 (18%) tropical cyclones did not have a Formation Alert.

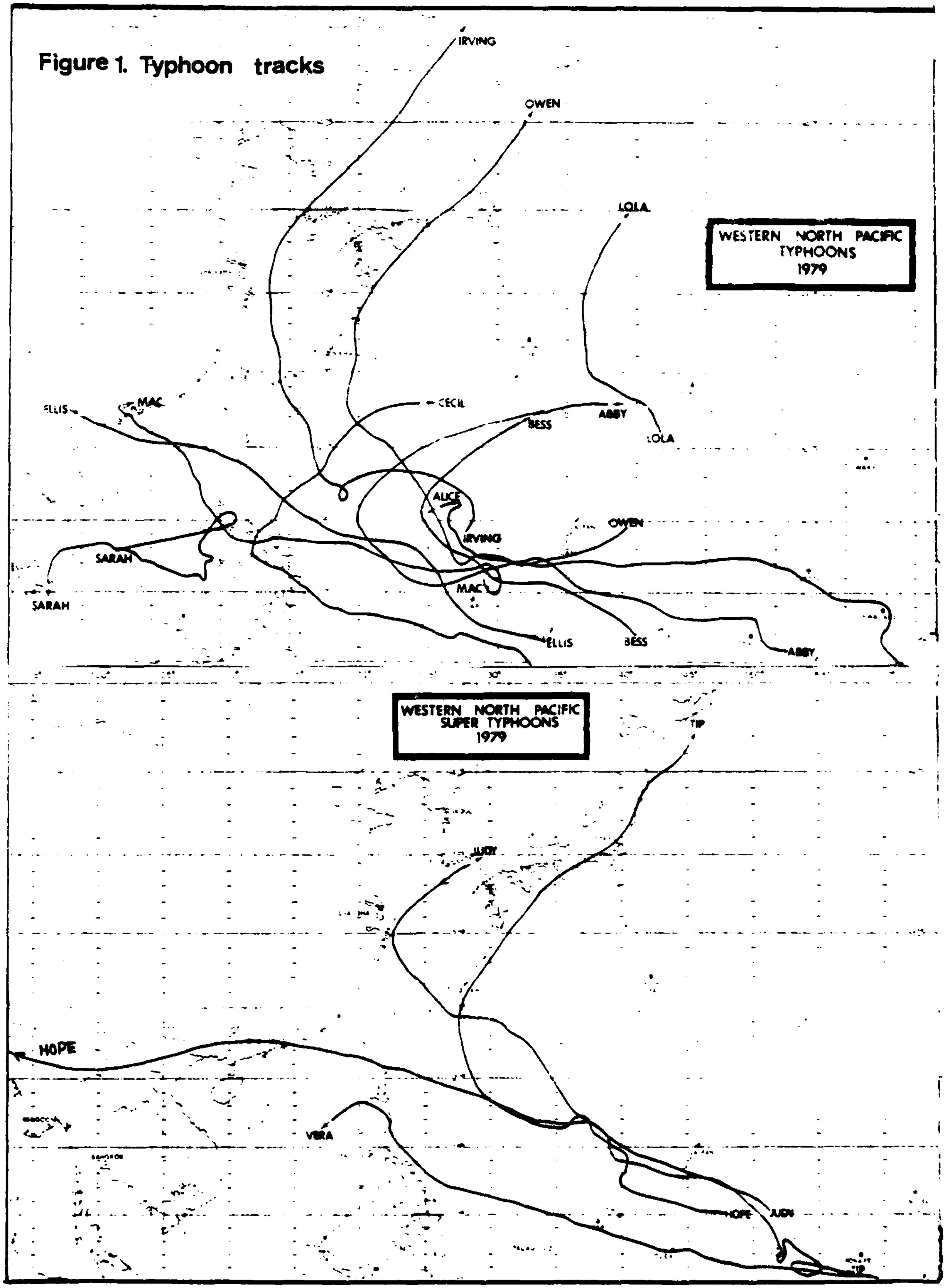
WARNINGS

Number of warning days: 149

Number of warning days with 2 cyclones: 38

Number of warning days with 3 or more cyclones: 5

Figure 1. Typhoon tracks



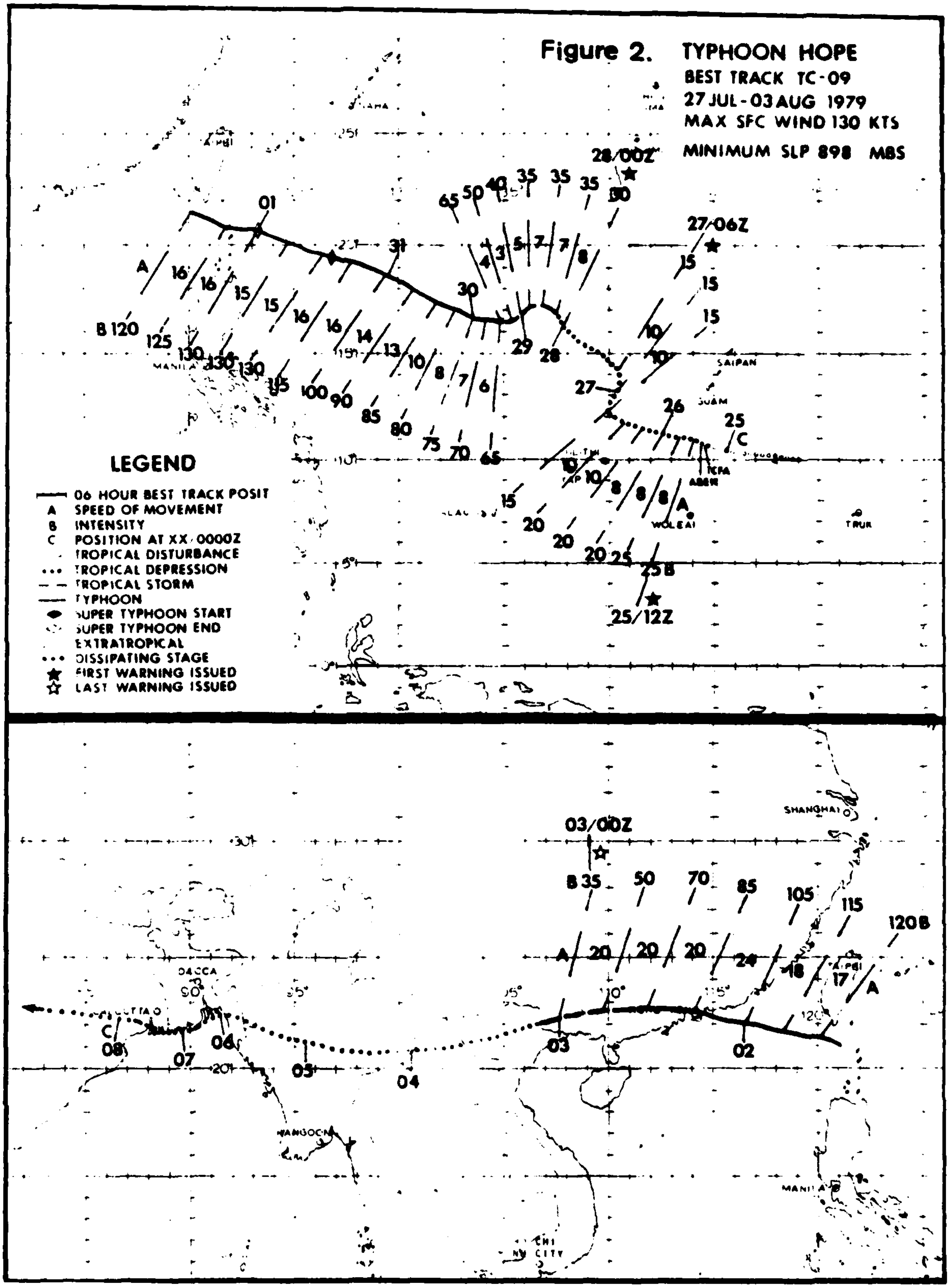


Figure 2. TYPHOON HOPE
BEST TRACK TC-09
27 JUL - 03 AUG 1979
MAX SFC WIND 130 KTS
MINIMUM SLP 898 MBS
LEGEND
06 HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
28/00Z
27/06Z
25/12Z
03/00Z
SAIPAN
GUAM
WOLEAI
TRUK
MANILA
SHANGHAI
DACCA
RANGOON
TAIPEI

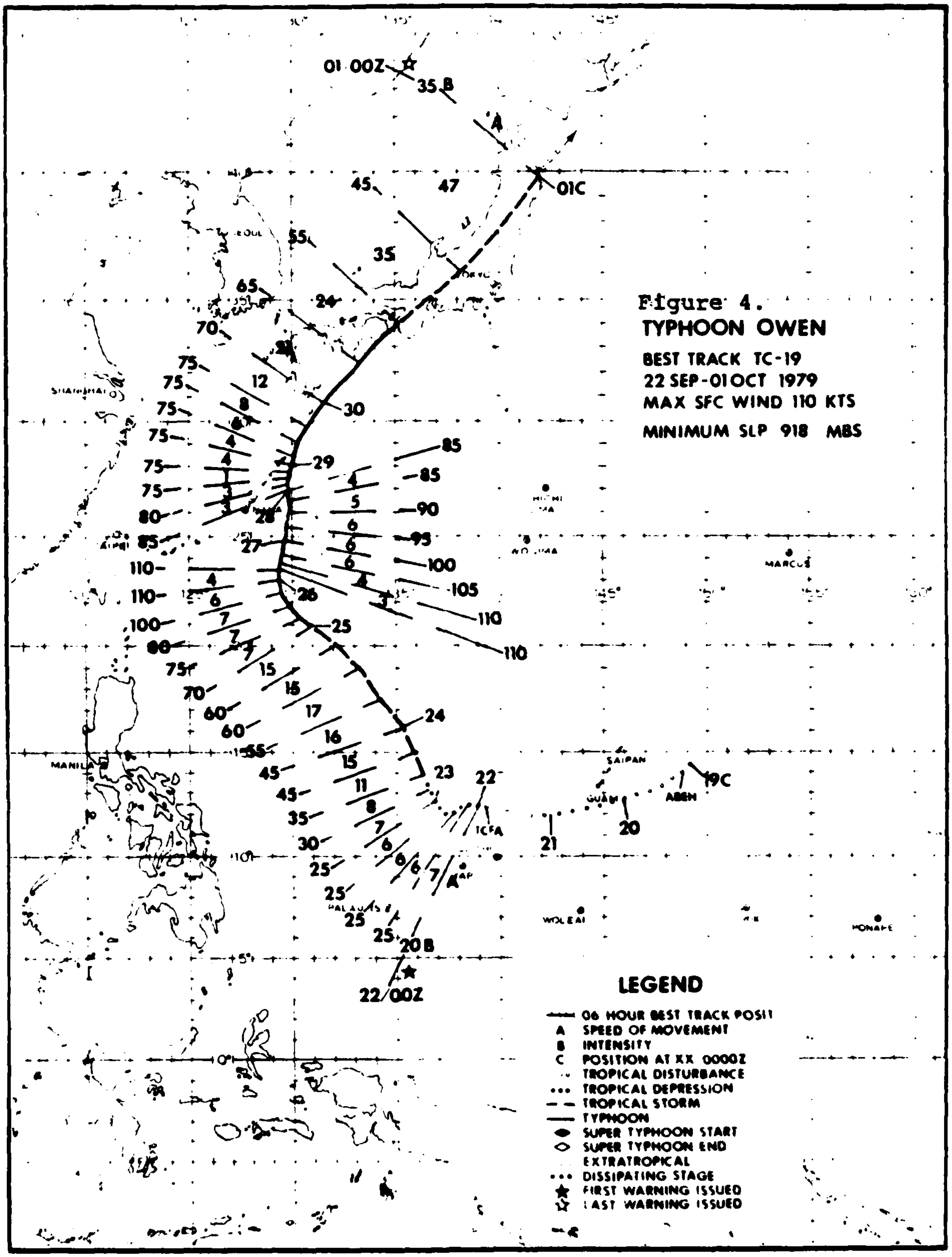


Figure 4.
TYPHOON OWEN
BEST TRACK TC-19
22 SEP-01 OCT 1979
MAX SFC WIND 110 KTS
MINIMUM SLP 918 MBS

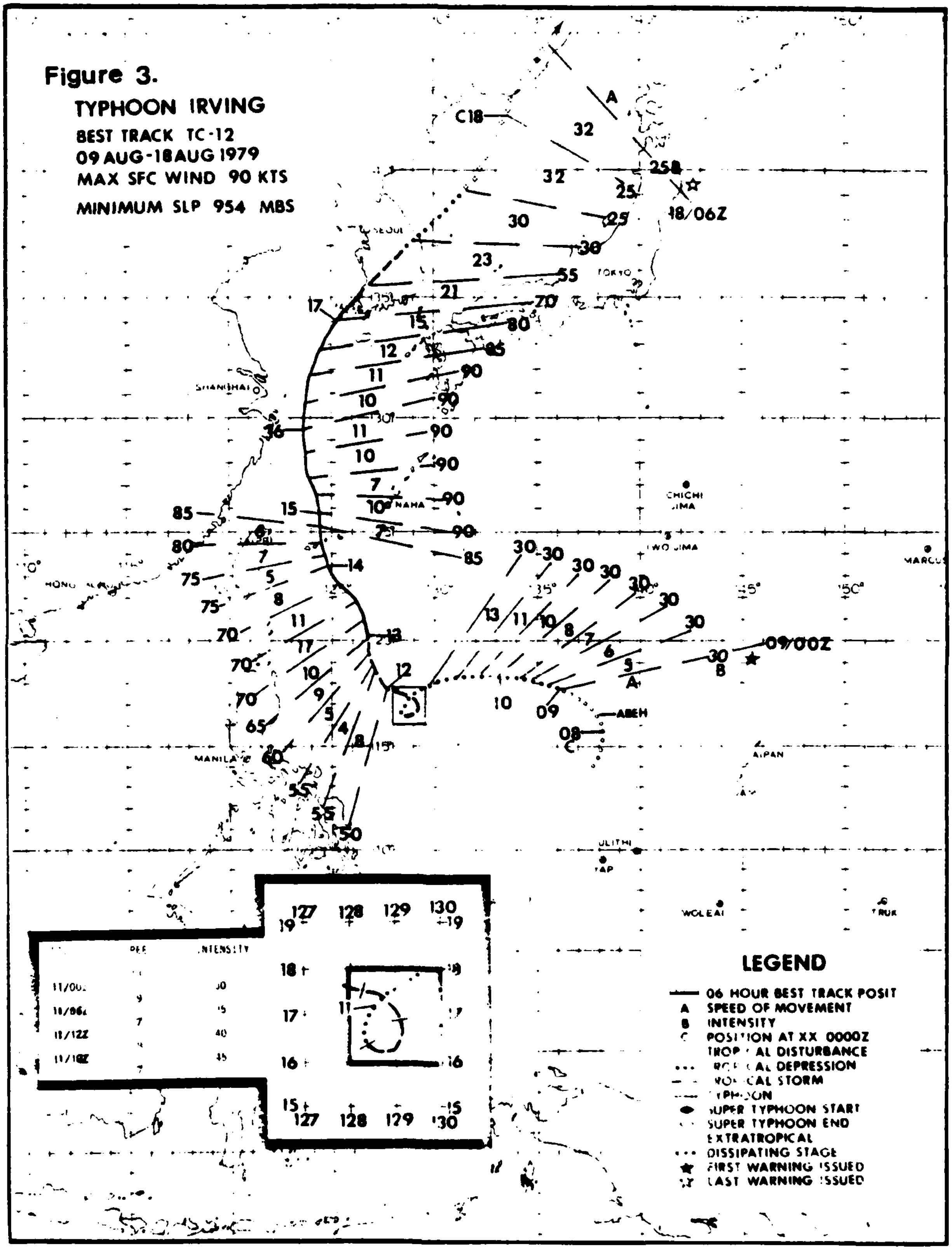


Figure 3.
TYPHOON IRVING
BEST TRACK TC-12
09 AUG-18AUG 1979
MAX SFC WIND 90 KTS
MINIMUM SLP 954 MBS

Table 3. Best track

SUPER TYPHOON HOPE

	BEST TRACK			WARNING			ERRORS		24 HOUR FORECAST			ERRORS		48 HOUR FORECAST			ERRORS		72 HOUR FORECAST			
MO/DA/HR	POSIT		WIND	POSIT		WIND	DST	WIND	POSIT		WIND	DST	WIND	POSIT		WIND	DST	WIND	POSIT		WIND	DST	WIND
072406Z	10.2	147.4	20	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
072412Z	10.3	146.4	20	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
072418Z	10.3	146.2	20	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
072500Z	10.4	145.5	20	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
072506Z	10.7	144.8	25	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
072512Z	10.9	144.0	25	11.0	144.1	25.	4.	0.	12.5	140.8	30.	66.	10.	13.8	137.0	35.	167.	15.	15.1	133.2	45.	267.	10.
072518Z	11.1	143.1	25	11.1	143.0	25.	14.	0.	12.3	139.8	30.	38.	15.	13.6	134.4	35.	246.	10.	15.0	130.3	45.	361.	10.
072600Z	11.2	142.4	20	11.1	142.7	20.	13.	0.	12.2	139.1	30.	92.	15.	13.6	134.0	35.	224.	5.	14.8	130.6	45.	395.	5.
072606Z	11.5	141.6	20	11.6	141.5	20.	4.	0.	12.7	137.8	30.	171.	15.	13.8	133.6	35.	246.	0.	15.2	129.2	45.	340.	-5.
072612Z	11.8	140.7	20	11.4	140.8	20.	4.	0.	13.0	137.0	30.	192.	10.	14.1	132.7	35.	304.	0.	15.7	128.5	40.	345.	-25.
072618Z	12.3	139.4	15	12.0	139.7	20.	13.	5.	13.4	135.7	30.	199.	5.	14.4	131.6	35.	305.	0.	15.7	127.0	45.	417.	-25.
072700Z	13.2	140.1	15	12.7	139.7	20.	44.	5.	14.4	135.6	25.	172.	-5.	14.0	131.6	30.	250.	-10.	17.8	127.5	35.	467.	-40.
072706Z	14.2	140.1	15	13.7	140.7	20.	34.	5.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
072712Z	15.0	139.4	20	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
072718Z	15.4	138.6	25	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
072800Z	16.1	137.8	30	16.2	137.8	25.	4.	-5.	18.6	133.6	40.	160.	0.	19.7	129.0	50.	240.	-25.	20.3	125.2	80.	297.	-40.
072806Z	16.8	137.5	35	17.5	138.4	25.	85.	-10.	20.7	136.4	40.	259.	-10.	23.1	133.1	50.	442.	-30.	20.3	129.6	80.	369.	-55.
072812Z	17.2	136.3	35	18.2	137.2	25.	62.	-10.	21.6	135.0	35.	305.	-30.	24.0	131.3	45.	395.	-40.	24.8	127.2	55.	376.	-75.
072818Z	17.1	136.2	35	19.0	136.4	25.	116.	-10.	22.2	134.5	35.	331.	-35.	24.6	129.0	45.	407.	-45.	20.0	125.3	55.	602.	-75.
072900Z	16.7	135.7	40	16.4	135.2	35.	23.	-5.	17.5	132.7	50.	85.	-25.	18.5	128.6	60.	46.	-40.	19.6	126.1	85.	95.	-55.
072906Z	16.6	135.4	50	16.2	135.1	40.	23.	-10.	16.2	132.8	50.	50.	-30.	17.1	130.1	60.	185.	-55.	18.6	127.2	85.	361.	-40.
072912Z	16.5	134.8	55	16.6	134.9	65.	8.	0.	17.1	132.4	75.	39.	-10.	18.4	129.3	85.	192.	-45.	20.3	125.7	95.	391.	-25.
072918Z	16.7	134.2	70	16.9	134.6	70.	19.	0.	17.3	131.8	80.	80.	-10.	18.7	128.7	85.	240.	-45.	20.6	125.1	95.	308.	-20.
073000Z	16.8	133.5	75	16.4	133.6	75.	9.	0.	18.0	130.2	90.	38.	-10.	19.7	126.9	100.	214.	-30.	20.0	122.4	100.	366.	-5.
073006Z	17.1	132.7	80	17.0	132.6	80.	4.	0.	18.2	129.6	90.	121.	-25.	19.4	126.3	100.	249.	-25.	21.0	122.3	100.	470.	15.
073012Z	17.4	131.8	85	17.2	132.0	90.	17.	5.	18.1	129.3	110.	147.	-20.	18.8	125.8	120.	336.	0.	21.0	121.8	115.	549.	65.
073018Z	18.0	130.6	90	17.5	131.1	95.	41.	5.	19.6	128.0	110.	197.	-20.	20.2	124.9	120.	306.	5.	21.3	120.8	110.	425.	60.
073100Z	18.6	129.4	100	19.5	129.3	100.	9.	0.	20.8	126.4	110.	90.	-20.	22.0	120.0	100.	200.	-5.	21.8	115.2	75.	627.	60.
073106Z	19.3	127.8	115	19.2	128.0	105.	11.	-10.	21.7	123.2	110.	104.	-15.	22.9	117.9	90.	222.	-5.	21.8	113.8	25.	679.	-45.
073112Z	19.6	126.2	130	19.7	126.0	130.	11.	0.	21.5	120.1	120.	0.	0.	24.0	115.7	35.	273.	-35.	0.0	0.0	0.	-0.	0.
073118Z	20.1	124.7	130	20.1	124.6	130.	6.	0.	22.0	118.6	120.	29.	5.	25.0	115.1	25.	333.	-25.	0.0	0.0	0.	-0.	0.
080100Z	20.6	123.2	130	20.7	123.2	130.	4.	0.	22.6	117.2	90.	50.	-15.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080106Z	20.8	121.6	125	20.8	121.5	125.	6.	0.	22.7	116.0	75.	116.	-10.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080112Z	21.5	120.1	120	21.6	120.0	120.	4.	0.	23.0	114.5	50.	155.	-20.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080118Z	21.7	118.2	115	21.9	118.4	115.	16.	0.	23.4	113.6	25.	225.	-25.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080200Z	22.2	116.6	105	22.0	116.5	105.	11.	0.	22.6	110.8	45.	103.	10.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080206Z	22.5	113.8	90	22.6	113.9	90.	4.	5.	23.1	108.5	30.	103.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080212Z	22.7	111.7	70	22.6	112.1	70.	23.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080218Z	22.6	109.4	50	22.7	110.1	60.	24.	10.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080300Z	22.2	107.4	35	22.5	108.0	35.	33.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080306Z	21.7	105.4	30	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080312Z	21.1	103.1	20	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080318Z	20.6	101.7	20	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080400Z	20.7	100.6	20	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080406Z	20.7	99.2	20	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080412Z	20.7	97.3	15	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080418Z	20.9	96.7	10	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080500Z	21.2	95.4	10	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080506Z	21.5	94.5	15	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080512Z	21.7	93.5	15	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080518Z	22.2	92.7	20	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080600Z	22.3	92.4	20	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080606Z	22.3	91.4	25	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080612Z	22.2	90.4	25	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080618Z	21.8	90.3	25	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080700Z	21.7	89.7	25	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080706Z	21.7	89.0	30	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080712Z	21.8	90.1	35	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080718Z	22.2	91.2	30	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080800Z	22.6	90.4	25	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080806Z	22.5	90.4	25	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080812Z	22.5	90.6	20	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.

ALL FORECASTS

	WRNG	24-HR	48-HR	72-HR
AVG FORECAST POSIT ERROR	23.	136.	265.	378.
AVG RIGHT ANGLE ERROR	16.	75.	160.	188.
AVG INTENSITY MAGNITUDE ERROR	3.	14.	22.	38.
AVG INTENSITY BIAS	-1.	-9.	-19.	-18.
NUMBER OF FORECASTS	33	28	23	21

Table 4. Best track

TYPHOON IRVING

DTG	BEST TRACK POSIT		BEST TRACK WIND	WARNING POSIT		WARNING WIND	WARNING ERRORS DST	WARNING ERRORS WIND	24 HOUR FORECAST POSIT		24 HR WIND	24 HR ERRORS DST	24 HR ERRORS WIND	48 HOUR FORECAST POSIT		48 HR WIND	48 HR ERRORS DST	48 HR ERRORS WIND	72 HOUR FORECAST POSIT		72 HR WIND	72 HR ERRORS DST	72 HR ERRORS WIND
080712Z	14.0	117.9	20	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080718Z	15.0	118.0	20	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
[illegible]	15.5	118.1	25	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
[illegible]	16.[illegible]	[illegible]	25	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
[illegible]	[illegible]	[illegible]	25	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
[illegible]	[illegible]	[illegible]	25	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.
080900Z	[illegible]	[illegible]	30	17.4	136.0	30.	5.	0.	19.9	132.[illegible]	35.	[illegible]	[illegible]	21.0	129.2	45.	224.	15.	21.5	126.0	55.	339.	5.
080906Z	[illegible]	[illegible]	30	19.3	135.1	30.	23.	0.	21.0	130.[illegible]	40.	180.		21.7	124.5	50.	386.	15.	22.0	119.5	60.	528.	5.
080912Z	[illegible]	[illegible]	30	19.1	135.2	30.	21.	0.	19.7	131.[illegible]	40.	[illegible]		21.1	129.5	50.	266.	10.	21.8	123.5	60.	266.	5.
080918Z	[illegible]	[illegible]	30	19.1	135.0	30.	44.	0.	19.8	134.[illegible]	40.	297.		21.7	130.0	35.	285.	10.	22.3	125.0	60.	311.	0.
081000Z	[illegible]	[illegible]	30	18.5	133.5	25.	13.	-5.	19.5	130.5	35.	82.	[illegible]	20.0	126.0	40.	182.	-10.	21.0	122.5	45.	262.	-20.
081006Z	[illegible]	[illegible]	30	19.4	132.7	25.	37.	-5.	20.1	129.[illegible]	35.	[illegible]	[illegible]	21.2	126.0	40.	179.	-15.	22.2	121.3	45.	301.	-25.
081012Z	18.3	131.1	30	19.7	131.0	30.	23.	0.	19.8	127.[illegible]	40.	[illegible]	[illegible]	21.1	123.0	45.	263.	-10.	21.0	118.8	50.	309.	-20.
081018Z	18.0	129.7	30	18.7	130.1	30.	44.	0.	19.4	125.7	40.	49.	-5.	21.0	121.0	45.	371.	-15.	21.0	116.9	50.	642.	-20.
081100Z	17.2	128.4	30	17.3	128.7	30.	4.	0.	17.1	126.0	45.	67.	-5.	18.8	120.0	40.	365.	-25.	14.8	115.5	50.	572.	-25.
081106Z	16.5	128.5	35	17.0	127.8	30.	50.	-5.	17.2	123.[illegible]	45.	96.	-10.	18.0	119.4	40.	423.	-30.	20.2	114.5	50.	613.	-25.
081112Z	16.3	129.0	40	17.2	129.2	35.	21.	-5.	18.3	125.[illegible]	[illegible]	40.	-10.	18.5	121.2	30.	361.	-20.	14.7	116.7	55.	521.	-25.
081118Z	17.5	128.4	45	17.9	128.8	40.	31.	-5.	19.0	124.4	[illegible]	120.	-10.	[illegible]	120.8	35.	338.	-15.	14.7	116.7	65.	517.	-20.
081200Z	17.8	127.6	50	17.5	128.2	55.	33.	5.	18.7	125.5	[illegible]	[illegible]	[illegible]	18.1	121.7	70.	321.	-5.	10.5	117.5	70.	535.	-20.
081206Z	18.4	127.1	55	17.9	127.5	55.	39.	0.	19.0	124.[illegible]	55.	38.	-5.	18.1	120.9	70.	366.	-5.	14.8	116.7	70.	587.	-20.
081212Z	18.7	126.3	55	18.5	126.5	55.	24.	0.	19.4	121.[illegible]	55.	[illegible]	-5.	18.9	119.0	70.	683.	-10.	14.9	115.5	75.	683.	-15.
081218Z	19.2	126.0	60	18.8	125.8	55.	61.	-5.	19.8	122.5	55.	126.	-6.	20.0	118.0	75.	639.	-10.	10.2	115.5	90.	713.	-10.
081300Z	20.3	126.7	65	20.1	126.8	65.	4.	0.	23.0	126.0	75.	50.	0.	27.0	127.5	90.	103.	-10.	29.9	141.0	80.	179.	-10.
081306Z	21.1	126.6	70	21.1	126.8	70.	11.	0.	25.0	120.6	75.	216.	1.	28.0	128.5	90.	269.	-10.	30.5	142.3	80.	473.	-10.
081312Z	22.0	126.0	70	22.0	126.6	70.	33.	0.	25.9	127.1	75.	135.	-5.	28.5	129.0	80.	103.	-10.	31.7	142.9	80.	467.	-5.
081318Z	22.7	125.5	70	23.2	125.7	70.	41.	0.	27.4	127.1	80.	203.	-5.	31.0	131.2	55.	416.	-5.	32.6	137.0	85.	443.	5.
081400Z	23.5	125.0	75	23.7	125.1	70.	13.	-5.	27.8	124.6	80.	120.	-10.	31.8	127.2	90.	223.	-10.	35.0	130.6	70.	282.	0.
081406Z	24.0	124.4	75	24.1	124.0	75.	4.	0.	27.4	125.2	85.	60.	-5.	31.2	126.8	80.	163.	-10.	34.5	140.0	70.	176.	15.
[illegible]	24.6	124.5	80	24.6	124.8	80.	16.	0.	30.8	126.7	100.	256.	10.	30.8	126.7	110.	162.	25.	36.6	129.8	85.	167.	55.
[illegible]	25.2	124.6	85	25.3	124.5	85.	8.	0.	28.2	126.0	105.	51.	15.	31.5	126.2	110.	146.	30.	36.7	129.5	80.	301.	55.
[illegible]	[illegible]	124.[illegible]	90	25.7	124.6	90.	13.	0.	28.5	126.0	100.	80.	10.	31.6	124.7	100.	144.	30.	36.6	127.5	80.	524.	55.
[illegible]	[illegible]	124.1	90	25.5	124.6	90.	29.	0.	29.1	126.2	95.	32.	5.	32.5	125.1	90.	201.	35.	35.2	128.1	75.	430.	55.
[illegible]	[illegible]	[illegible]	90	25.5	123.9	90.	11.	0.	30.5	121.6	95.	72.	10.	33.4	125.1	90.	270.	60.	0.0	0.0	0.	-0.	[illegible]
[illegible]	[illegible]	123.7	90	25.3	123.8	90.	13.	0.	31.5	121.6	95.	78.	15.	36.7	126.0	50.	185.	35.	0.0	0.0	0.	-0.	[illegible]
[illegible]	[illegible]	[illegible]	90	29.5	123.7	95.	4.	5.	31.5	126.0	85.	39.	15.	37.1	127.7	80.	147.	35.	0.0	0.0	0.	-0.	0.
[illegible]	30.5	123.7	90	31.1	123.8	90.	30.	0.	36.7	125.6	80.	50.	25.	40.8	131.5	45.	282.	20.	0.0	0.0	0.	-0.	[illegible]
[illegible]	31.7	123.7	85	31.5	123.7	90.	4.	5.	36.5	126.5	80.	219.	50.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	[illegible]
[illegible]	32.9	123.0	80	32.8	123.8	80.	10.	0.	37.3	126.5	75.	285.	50.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	.
[illegible]	34.0	125.0	75	34.1	124.9	70.	4.	0.	18.7	128.8	50.	241.	25.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	.
[illegible]	35.6	126.7	55	35.2	126.2	60.	34.	5.	39.1	130.9	35.	362.	10.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	[illegible]
[illegible]	37.1	128.0	30	36.6	128.6	30.	33.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	.
081712Z	39.5	131.6	25	39.3	131.4	30.	36.	5.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	.
081800Z	42.0	133.5	25	42.1	134.3	25.	36.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	.
081806Z	44.2	135.3	25	44.9	137.0	25.	81.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	.

ALL FORECASTS	WRNG	24-HR	48-HR	72-HR
AVG FORECAST POSIT ERROR	26.	143.	285.	44[illegible].
AVG RIGHT ANGLE ERROR	17.	98.	203.	344.
AVG INTENSITY MAGNITUDE ERROR	2.	11.	19.	20.
AVG INTENSITY BIAS	-0.	6.	3.	-1[illegible].
NUMBER OF FORECASTS	38	34	30	25

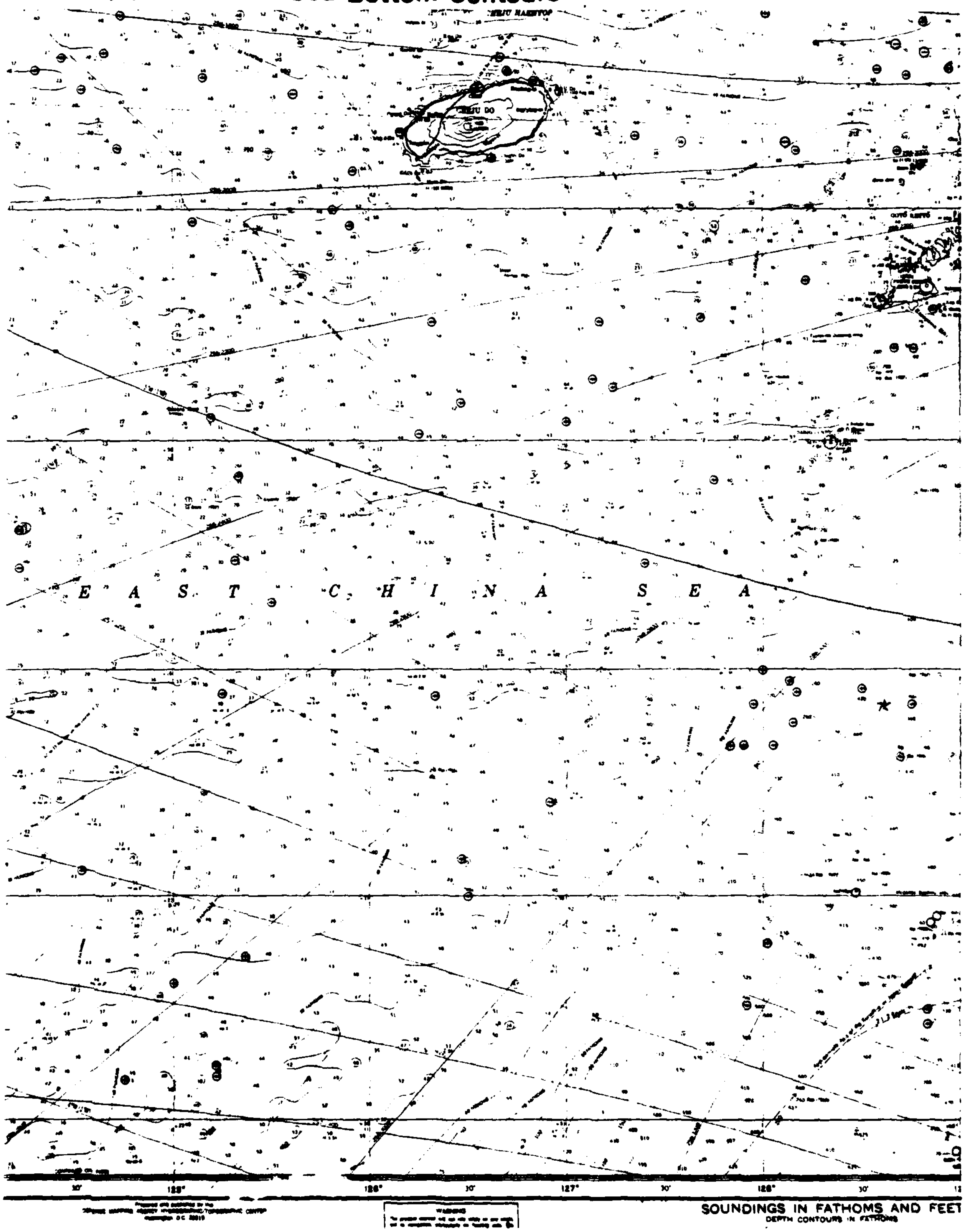
Table 5. Best track

TYPHOON [illegible]

DTG	BEST TRACK POSIT		BEST TRACK WIND	WARNING POSIT		WARNING WIND	WARNING ERRORS DST	WARNING ERRORS WIND	24 HOUR FORECAST POSIT		24 HR WIND	24 HR ERRORS DST	24 HR ERRORS WIND	48 HOUR FORECAST POSIT		48 HR WIND	48 HR ERRORS DST	48 HR ERRORS WIND	72 HOUR FORECAST POSIT		72 HR WIND	72 HR ERRORS DST	72 HR ERRORS WIND
092200Z	12.5	138.[illegible]	[illegible]	13.0	138.0	20.	54.	0.	13.6	134.0	40.	123.	15.	14.4	131.8	50.	223.	15.	14.9	129.5	70.	[illegible]	[illegible]
092206Z	12.5	138.[illegible]	25	12.9	138.0	25.	25.	0.	13.6	136.0	45.	99.	15.	14.6	131.7	50.	234.	5.	14.9	129.5	70.	147.	-5.
092212Z	12.1	137.	[illegible]	12.5	137.3	25.	33.	0.	12.9	136.0	35.	161.	0.	13.8	130.9	45.	437.	-15.	15.5	129.2	55.	[illegible]	-25.
092218Z	12.1	137.2	25	12.1	136.3	25.	56.	[illegible]	12.7	132.7	35.	220.	-10.	13.6	129.1	50.	426.	-10.	15.3	125.0	60.	[illegible]	-40.
092300Z	12.5	136.2	25	12.3	136.7	25.	21.	0.	12.6	134.5	30.	220.	-15.	12.7	131.2	35.	447.	-35.	14.2	125.0	45.	[illegible]	-45.
092306Z	13.3	136.6	[illegible]	12.3	136.3	30.	66.	1.	12.6	133.6	45.	313.	-10.	12.4	130.3	55.	719.	-20.	14.3	127.1	60.	421.	-50.
092312Z	13.9	136.2	[illegible]	13.7	136.1	45.	34.	10.	13.0	134.1	50.	309.	-10.	14.7	131.6	50.	465.	-20.	15.6	129.2	70.	536.	-40.
092318Z	15.0	135.8	45	13.7	135.6	45.	73.	0.	14.4	133.1	55.	132.	-5.	15.6	129.9	55.	441.	-35.	16.3	128.2	75.	419.	-30.
092400Z	16.1	135.1	45	15.6	135.2	45.	13.	0.	21.0	132.6	60.	45.	-10.	26.8	131.1	55.	44.	-45.	24.6	132.3	70.	246.	-40.
092406Z	17.7	134.1	55	17.4	134.5	55.	13.	0.	22.1	131.8	55.	46.	-10.	26.0	131.3	70.	43.	-40.	24.6	133.2	75.	239.	-20.
092412Z	19.0	133.2	[illegible]	19.2	133.6	80.	16.	0.	24.9	130.6	75.	179.	-5.	27.4	130.2	55.	150.	-25.	30.6	132.0	73.	347.	-20.
092418Z	20.1	132.1	[illegible]	20.7	132.3	80.	34.	0.	25.4	130.3	75.	499.	-25.	28.7	130.5	55.	[illegible]	-20.	31.0	132.4	70.	336.	-15.
092500Z	21.0	130.7	70	20.4	130.8	70.	4.	0.	23.8	127.0	85.	[illegible]	-25.	26.2	125.0	45.	214.	-5.	24.6	125.6	80.	262.	-5.
092506Z	21.3	130.1	75	21.7	130.0	75.	29.	0.	26.1	127.1	85.	[illegible]	-25.	26.2	125.8	45.	216.	0.	24.3	127.0	75.	100.	-5.
092512Z	22.3	129.[illegible]	[illegible]	21.9	129.6	90.	21.	0.	26.7	127.0	95.	[illegible]	-15.	27.1	126.5	45.	144.	5.	30.7	125.4	75.	132.	0.
092518Z	22.6	129.[illegible]	[illegible]	22.5	129.0	90.	29.	-10.	26.0	127.6	100.	[illegible]	-5.	27.5	127.0	45.	161.	10.	30.3	110.0	73.	130.	-5.
092600Z	23.1	129.1	11[illegible]	23.3	124.2	95.	14.	-15.	25.5	120.7	110.	50.	[illegible]	27.8	130.0	40.	44.	5.	30.3	116.0	70.	261.	-5.
092606Z	23.5	129.2	110	23.7	124.0	100.	16.	-10.	26.0	124.5	110.	[illegible]	15.	28.7	131.1	55.	119.	5.	31.2	116.3	65.	159.	-10.
092612Z	[illegible]	[illegible]	110	24.0	129.1	100.	15.	-10.	26.0	124.0	113.	[illegible]	[illegible]	28.6	130.6	45.	46.	10.	30.4	115.5	65.	240.	-10.
092618Z	24.6	[illegible]	[illegible]	24.6	129.5	105.	5.	0.	29.0	130.0	75.	159.	-10.	26.0	132.1	45.	115.	0.	31.1	117.0	55.	314.	-20.
092700Z	26.4	129.6	100	26.9	129.4	100.	12.	0.	26.6	124.0	95.	36.	10.	28.4	131.7	70.	49.	-5.	31.6	117.7	50.	120.	-20.
092706Z	25.5	129.7	95	25.3	129.7	95.	12.	0.	27.9	130.4	90.	32.	10.	20.2	132.7	55.	102.	-10.	32.3	119.0	45.	267.	-20.
092712Z	26.0	129.4	90	25.9	129.9	90.	4.	1.	18.9	131.1	85.	40.	[illegible]	10.4	133.9	55.	212.	-10.	33.3	118.5	45.	179.	-10.
092718Z	26.5	129.4	85	26.6	124.7	85.	4.	.	29.0	130.4	75.	47.	.	31.5	133.7	50.	149.	-15.	34.0	119.5	45.	131.	0.
092800Z	27.0	129.8	85	27.1	129.0	95.	4.	[illegible]	29.6	130.7	75.	18.	[illegible]	37.2	133.8	50.	166.	-10.	35.0	140.1	40.	237.	5.
092806Z	27.3	129.4	80	27.5	129.0	90.	[illegible]	.	40.3	131.1	75.	124.	[illegible]	33.8	135.1	55.	103.	-10.	0.0	0.0	0.	-0.	[illegible]
092812Z	27.6	129.4	75	27.7	129.0	75.	6	.	29.5	130.0	70.	29.	-5.	32.4	132.0	50.	144.	5.	0.0	0.0	0.	-0.	[illegible]
092818Z	27.8	129.4	75	27.7	124.4	75.	5.	.	28.8	124.0	70.	80.	-5.	41.2	131.2	50.	456.	15.	0.0	0.0	0.	-0.	.
092900Z	28.1	129.3	75	28.0	129.4	75.	3.	.	34.8	130.4	73.	56.	.	42.9	132.5	50.	611.	25.	0.0	0.0	0.	-0.	[illegible]
092906Z	28.5	130.1	75	28.7	129.0	75.	[illegible]	.	42.8	131.5	40.	40.	-25.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	.
092912Z	29.1	130.1	75	29.1	130.2	75.	.	[illegible]	42.3	131.8	35.	[illegible]	.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	[illegible]
092918Z	29.0	[illegible]	75	29.7	130.6	75.	5.	.	42.0	132.4	50.	[illegible]	[illegible]	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	[illegible]
093000Z	30.0	131.[illegible]	70	31.0	131.5	[illegible]	[illegible]	[illegible]	45.0	134.5	10.	[illegible]	.	0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	[illegible]
093006Z	32.0	131.[illegible]	65	32.0	132.5	.	34.	.	0.0	0.0	0.	-0.		0.0	0.0	0.	-0.	0.	0.0	0.0	0.	-0.	[illegible]
093012Z	34.1	135.1	60	33.4	134.5	.	33.	.	0.0	0.0	0.	-0.		[illegible]	0.0	.	-0.	0.	0.0	0.0	0.	-0.	.
093018Z	[illegible]	[illegible]	45	35.0	137.0	30.	[illegible]		0.0	0.0	0.	[illegible]		[illegible]	[illegible]	0.	-0.	0.	0.0	0.0	0.	-0.	[illegible]
100100Z	39.4	141.[illegible]	35	39.0	141.3	35.	55.		0.0	0.0	0.	.	.	.	.	0.	-0.	0.	0.0	0.0	0.	-0.	[illegible]

ALL FCST	WRNG	24-HR	48-HR	72-HR
AVG FORECAST POSIT ERROR	25.	[illegible]	[illegible]	337.
AVG RIGHT ANGLE ERROR	15.	[illegible]		256.
AVG INTENSITY MAGNITUDE ERROR	2.			18.
AVG INTENSITY BIAS	-0.	-1.	[illegible]	-18.
NUMBER OF FORECASTS	37	33	9	25

MAP 1. East China Sea Bottom Contours



The dispersive arrival at the prediction site of the waves propagating from a single source region is represented by a plot of period versus arrival time in Figures 9, 10 and 11. The energy in each low frequency (7~19 sec) spectral component of the swell at Cheju-do is calculated by modifying the energy spectrum at the source for the refraction and shoaling. The lowest period ($\bar{T}$ = 4 sec) is assumed totally eliminated by attenuation.

The total propagated energy at any given time is estimated by summing all the directional components. The predicted swell heights $H\,1/10$ are assumed to be related to the energy by $H\,1/10 = K\sqrt{E}$, where K is constant (0.4) and E is energy in a unit of $2^6 \cdot$ kiloerg/cm^2 and H 1/10 is in meters.

By graphing the energy associated with the 5 mean period bands as a function of arrival time at the forecast site and summing, then a plot of the total propagated energy is obtained (see Figures 13, 15 and 17). This plot is compared with the observed wave heights in Chapter IV-D.

E. TERMINOLOGY

To make clear the notation used in this study, the following terms and symbols are defined.

sea - Those waves found within a generating area.

swell - Those waves which have moved out of a generating area.

R_o - The distance from the source to the "bottom line" where the corresponding periods feel "bottom" i.e., the swell travel distance in deep water. The depth at the "bottom line" is $h = \frac{L_o}{2}$.

R - The distance from the "bottom line" to the forecast site.

$\bar{T}$ - The mean period in a spectral band ($\bar{T} = 1/\bar{f}$).

H 1/10 - The average heights of the 1/10 highest waves.

H 1/3 - The average heights of the 1/3 highest waves (significant wave height).

tar - The swell arrival time (GMT).

t - The swell travel time.

L - Wavelength (L_o in deep water).

Cg - Group velocity (Cg_o in deep water).

C - Phase speed (Co in deep water).

D - The total swell travel distance ($D = R_o + R$).

g - Acceleration of gravity

σ - Wave angular frequency ($2\pi/L$).

k - Wave number ($2\pi/L$).

h(d) - The ater depth.

α_o - The angle between wave crest and bottom contour at the depth, $h = \frac{L_o}{2}$.

T_4 - The total energy at grid point 4 in the generating area.

D_4 - The directional energy component at grid point 4 in generating area.

Wave spectrum (energy spectrum) - The distribution of either wave height or energy with period. The potential energy of the sea surface is proportional to the mean of the square of the wave height.

Dispersion - A process which leads to longitudinal spreading of the wave energy as, in deep water, energy in each spectral component is propagated at a characteristic group velocity Cg, the long waves having the larger group velocity.

$\bar{\theta}$ - The mean directional bands of 16 unit points rose.

H'_o - The wave height before refraction in deep water.

II. PREDICTION OF TROPICAL STORM WAVES BY TYWAVES

A. LOCATION OF THE SELECTED POINT-SOURCES

The TYWAVES program produces a printout of the complete energy spectrum for 12 points around each typhoon. Each point lies at a chosen distance from the storm center in a fixed direction, no matter what the storm movement direction is. These points are representative origins of the wave energy emerging from the typhoon.

Only those points are selected which are in the region of maximum winds and where important energy components are directed toward the distant prediction site.

The arrangement of points whose wave spectra are used in this study is shown below.

		+9		
	+5	+1	+6	
+11	+3	+	+4	+12
	+7	+2	+8	
		+10		

The distances from the storm center to points 1, 2, 3 and 4 are three grid-lengths (3 x 40 = 120 NM), to 9, 10, 11 and 12 are five grid lengths (5 x 40 = 200 NM), and to

5, 6, 7 and 8 are $3 \times \sqrt{2}$ grid lengths ($3 \times \sqrt{2} \times 40 \approx 170$ NM), respectively.

Among the 12 points, only points 4, 6, 8 and 12 were selected as sources, because the spectral energy from only these 4 points can propagate to Cheju-do, Korea (33.2°N 126.6°E).

The locations of the sources for each time of interest for the three storms are shown below in Table VI, which was derived and calculated from the postanalysis "best track" data shown in Tables III, IV, and V [2]. The relationship between latitude and longitude is:

$$\text{Lat.} = \text{Long.} \times \cos(\text{Lat.})$$

$$= \text{Long.} \times \cos\{(\text{storm center} + \text{forecast})/2\}_{\text{lat}}$$

e.g.:

When the storm center (best track) is 20.0°N 126.7°E, point 4 is same lat (20.0°N), but 120 NM (2° in lat) east of the center.

$$\text{Thus, } 2^\circ \text{ Lat} = {}^\circ\text{Long} \times \cos\left(\frac{20.0 + 20.0}{2}\right)$$

$$= {}^\circ\text{Long} \times \cos 10^\circ$$

$$\therefore {}^\circ \text{ Long} = 2^\circ \text{ Lat}/\cos 10^\circ = 2.128^\circ \text{ E}$$

$$= 126.7 + 2.128$$

$$= 128.8^\circ \text{ E}$$

Therefore, point 4 $\approx$ 20.0°N 128.8°E.

TABLE 6

Typhoon Centers and Selected Points Location

Name	Date (GMT)	Center (^{o}N-^{o}E)	PT4 (^{o}N-^{o}E)	PT6 (^{o}N-^{o}E)	PT8 (^{o}N-^{o}E)	PT12 (^{o}N-^{o}E)
HOPE	073012	17.4-131.8	17.4-133.9	19.4-133.9	15.4-133.9	17.4-135.3
	073100	18.6-129.4	18.6-131.5	20.6-131.5	16.6-131.5	18.6-132.9
	073112	19.6-126.2	19.6-128.3	21.6-128.3	17.6-128.3	19.6-129.7
	080100	20.6-123.2	20.6-125.3	22.6-125.4	18.6-125.3	20.6-126.8
	080112	21.5-120.1	21.5-122.2	23.5-122.3	19.5-122.2	21.5-123.7
IRVING	081300	20.0-126.7	20.0-128.8	22.0-128.8	18.0-128.8	20.0-130.2
	081312	22.0-126.0	22.0-128.2	24.0-128.2	20.0-128.1	22.0-129.6
	081400	23.5-125.0	23.5-127.2	25.5-127.2	21.5-127.2	23.5-128.6
	081412	24.6-124.5	24.6-126.7	26.6-126.7	22.6-126.7	24.6-128.2
	081500	25.9-124.3	25.9-126.5	27.9-126.5	23.9-126.5	25.9-128.0
	081512	27.5-123.7	27.5-126.0	29.5-126.0	25.5-125.9	27.5-127.5
	081600	29.6-123.7	29.6-126.0	31.6-126.0	27.6-126.0	29.6-127.5
	081612	31.7-123.7	31.7-126.1	33.7-126.1	29.7-126.1	31.7-127.6
OWEN	092506	21.3-130.3	21.3-132.4	23.3-132.5	19.3-132.4	21.3-133.9
	092518	22.6-129.5	22.6-131.7	24.6-131.7	20.6-131.7	22.6-133.1
	092606	23.5-129.2	23.5-131.4	25.5-131.4	21.5-131.4	23.5-132.8
	092618	24.4-129.4	24.4-131.6	26.4-131.6	22.4-131.6	24.4-133.3
	092706	25.5-129.7	25.5-131.9	27.5-131.9	23.5-131.9	25.5-133.4
	092718	26.5-129.8	26.5-131.9	28.5-132.1	24.5-132.0	26.5-133.5
	092806	27.3-129.8	27.3-132.1	29.3-132.1	25.3-132.0	27.3-133.5
	092818	27.8-129.8	27.8-132.1	29.8-132.1	25.8-132.0	27.8-133.6
	092906	28.5-130.1	28.5-132.4	30.5-132.4	26.5-132.4	28.5-133.9
	092918	29.8-130.6	29.8-132.9	31.8-132.9	27.8-132.9	29.8-134.4

B. SEA-SPECTRA AT THE POINT SOURCES

The description of the wave fields using the spectral component method developed by NEPRF was used in this study. Only those directional components able to propagate to the forecast site need be considered.

A schematic example of the TYWAVES spectral prediction in a typhoon area is given below. The whole spectral table for the selected sources is shown in Appendix B.

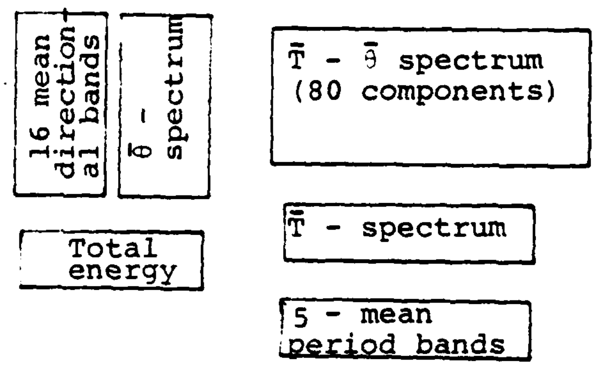


Table VII is one example of a period-direction spectrum at source point 4 in Typhoon Owen, at 06 on 25 September 1979.

The mean period is 13 sec with the maximum energy 86 (2^6· kiloeng/cm^2) in the dominant period. The dominant wave direction is SE, but the energy from that direction will not arrive at the forecast site, only the SSE component will arrive at the site (as seen in Figure 5).

C. SELECTION OF THE DIRECTIONAL ENERGY AT POINT SOURCES

A constant energy was assumed between parallel rays separated by width 80~160 NM (2-4 grid length), which is 40~80 NM right at the grid point depending upon the typhoon size. This is why the energy in each component is assumed constant along the deep water propagation path. As example of possible refraction diagrams under the above consideration and bottom contours in Map 1 is shown in Figure 5.

Only the SSE component was considered to propagate to the forecast site. The SE component would refract toward China, west of Cheju-do, and the S component would pass to the east of Cheju-do as seen in Figure 5.

All the directional components were chosen in the same way, and are underlined as shown in Table 7.

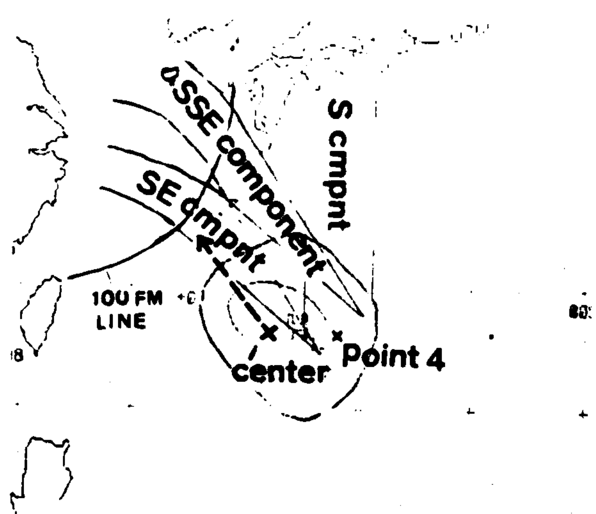


Figure 5. Possible refraction diagram at point 4 at 06 GMT September 25, 1979. The curves around typhoon center are contours of wave height (H 1/3 in feet). The detailed bottom contours are shown on Map 1.

TABLE 7

Period-Directional Spectrum at Point 4 at 06 GMT September 25, 1979. The energy units are 2^6 · kiloerg/cm^2.

TYPHOON WAVES POINT 4

H.1/10= 5,1 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	*	0	0	0	0	0	0
NNE	0	*	0	0	0	0	0	0
NE	0	*	0	0	0	0	0	0
ENE	0	*	0	0	0	0	0	0
E	1	*	0	0	0	0	0	0
ESE	32	*	0	6	6	17	1	0
SE	93	*	0	8	25	27	24	8
SSE	74	*	0	7	[illegible]	[illegible]	8	0
S	31	*	0	4	[illegible]	[illegible]	4	2
SSW	0	*	0	0	0	0	0	0
SW	0	*	0	0	0	0	0	0
WSW	0	*	0	0	0	0	0	0
W	0	*	0	0	0	0	0	0
WNW	0	*	0	0	0	0	0	0
NW	0	*	0	0	0	0	0	0
NNW	0	*	0	0	0	0	0	0
TOTAL	232		0	26	69	96	38	10
	PERIODS		4	7	10	13	16	19

D. TOTAL AND DIRECTIONAL ENERGIES AT POINT SOURCES

Figures 6, 7 and 8 show the energy components at each selected grid point in the typhoon area. Each line is labeled by selected grid point (source point). T_n indicates total energy given by TYWAVES at point n and D_n represents the sum over all periods of the energies with proper direction to reach Cheju-do.

$$D_n(\theta_o) = \sum_{i=1}^{19} E_i \; (\bar{T}_i,\; \theta_o)$$

For example, where n = 12, θ is SE, then

$$D_{12}(\theta\text{=SE}) = E_7\;(\bar{T}\text{=4},\; \theta_o\text{=SE}) + E_{10}\;(\bar{T}\text{=10},\; \theta_o\text{=SE})$$
$$+ E_{13}\;(\bar{T}\text{=13},\; \theta_o\text{=SE}) + E_{16}\;(\bar{T}\text{=16},\; \theta_o\text{=SE})$$
$$+ E_{19}\;(\bar{T}\text{=19},\; \theta_o\text{=SE}).$$

This represents the total energy at point 12 directed from SE toward Cheju-do.

The energy is in practice converted into height H 1/10 by making H 1/10 = 0.4 $\sqrt{E}$, which is described in Chapter I.D. Some special features of the wave fields in each source are now discussed.

1. <u>Typhoon Hope</u>

The maximum sustained wind speed was over 100 kts for two days from 00 GMT July 31. The maximum wave height (H 1/10) recorded was 12.80 m. The directional energy components from grid point 12 were ignored from 00 GMT July 31 to 00 GMT August 01, because they were too small.

2. <u>Typhoon Irving</u>

Only the propagation of energy components until 00 GMT August 16 was considered, because the forecast site is inside of typhoon area after that time. Therefore, after 00 GMT August 16, the propagated wave energy should be combined with local energy at prediction site.

Among the directional components, only those from grid points 4 and 12 were propagated to the prediction site during the typhoon period, because the energies from other sources were refracted away from Cheju-do.

3. Typhoon Owen

After 06 GMT September 29, the typhoon passed east of southern Japan. No further propagation to Cheju-do occurred.

In most cases, only one directional energy component was selected at each grid point. But both components (SE and SSE) were able to reach the forecast site on 18 GMT September 27, from grid point 4, because of the width of their ray boundaries at distances near the source.

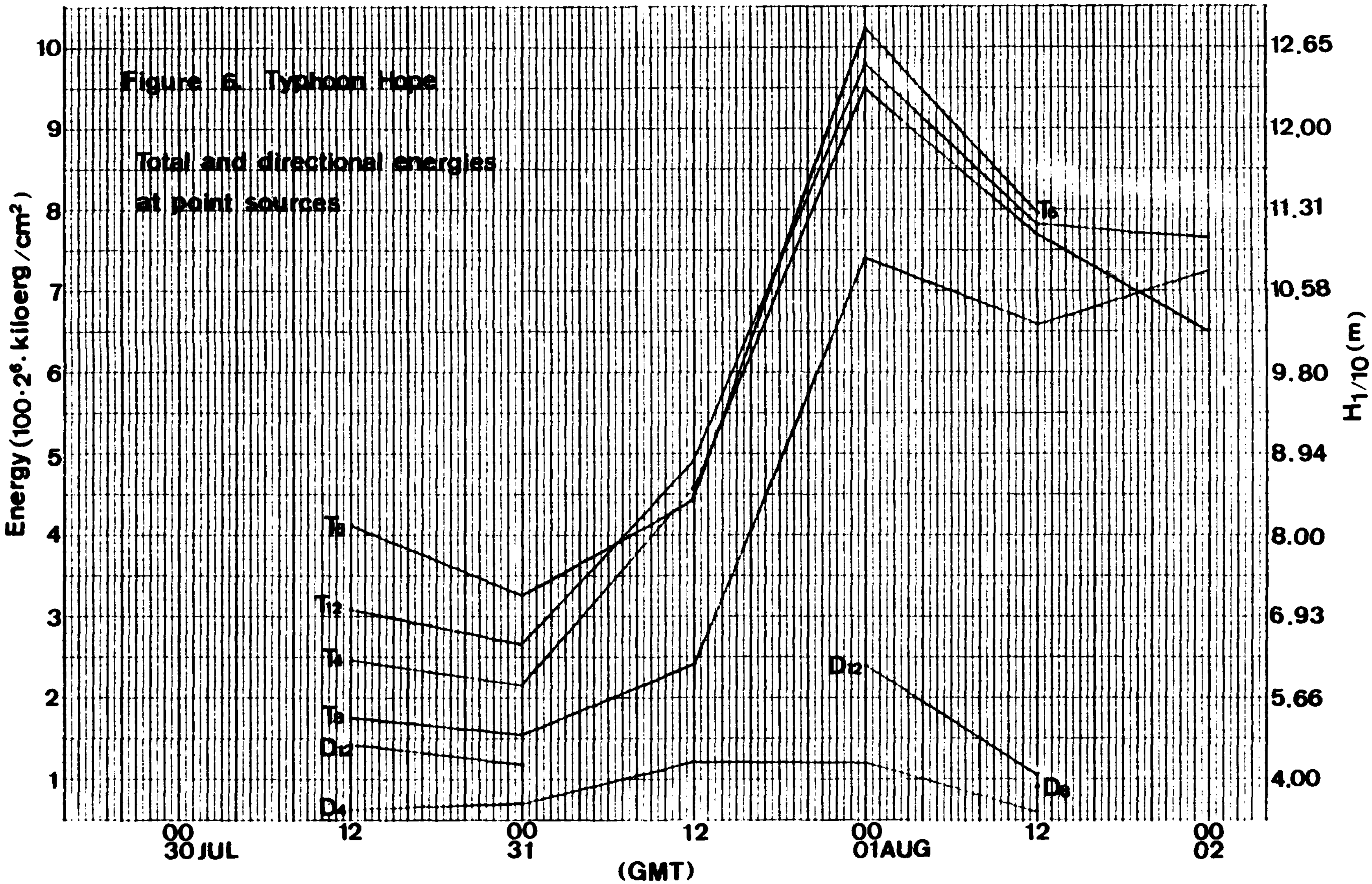


Figure 6. Typhoon Hope

Total and directional energies at point sources

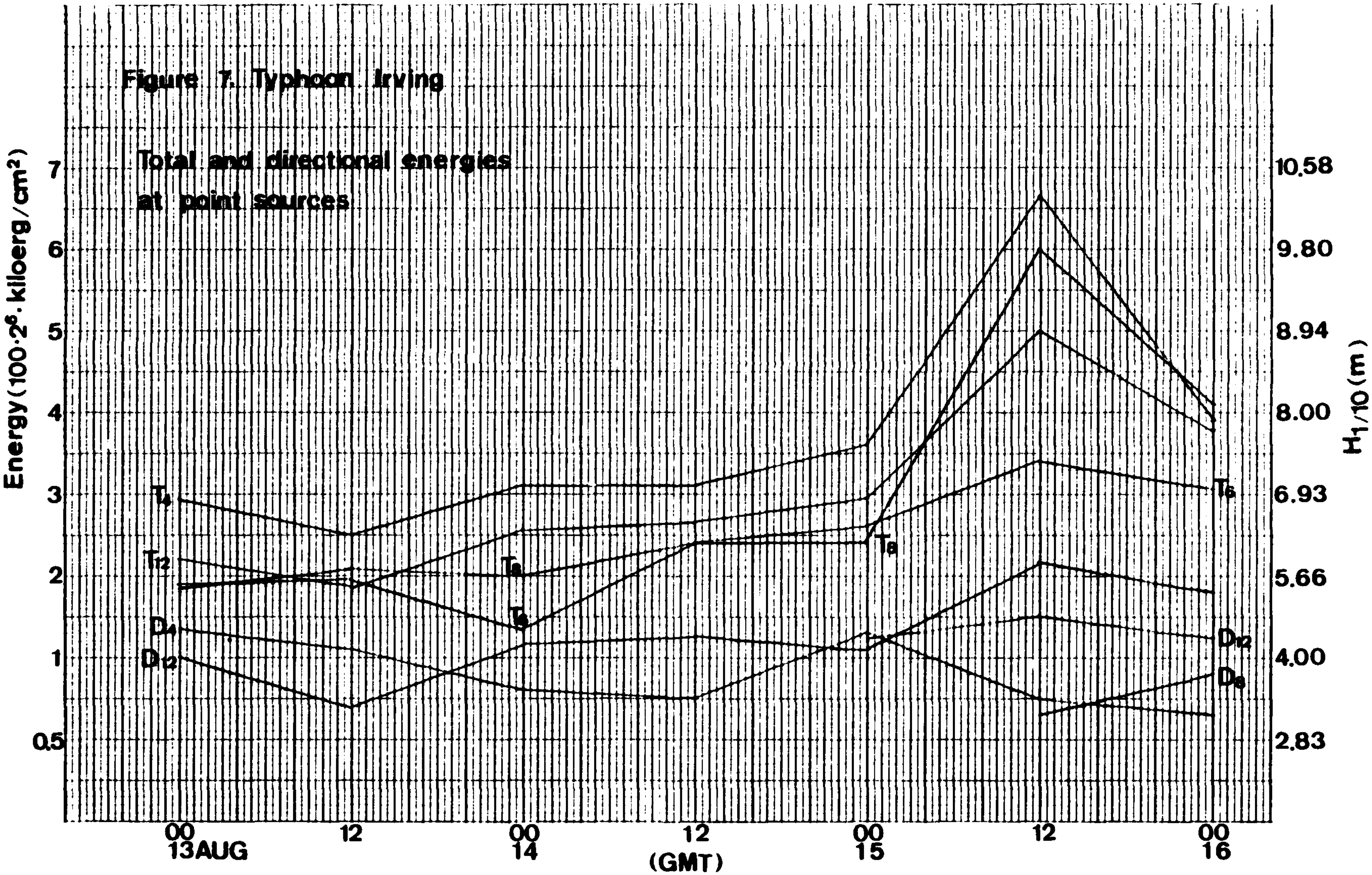


Figure 7. Typhoon Irving

Total and directional energies at point sources

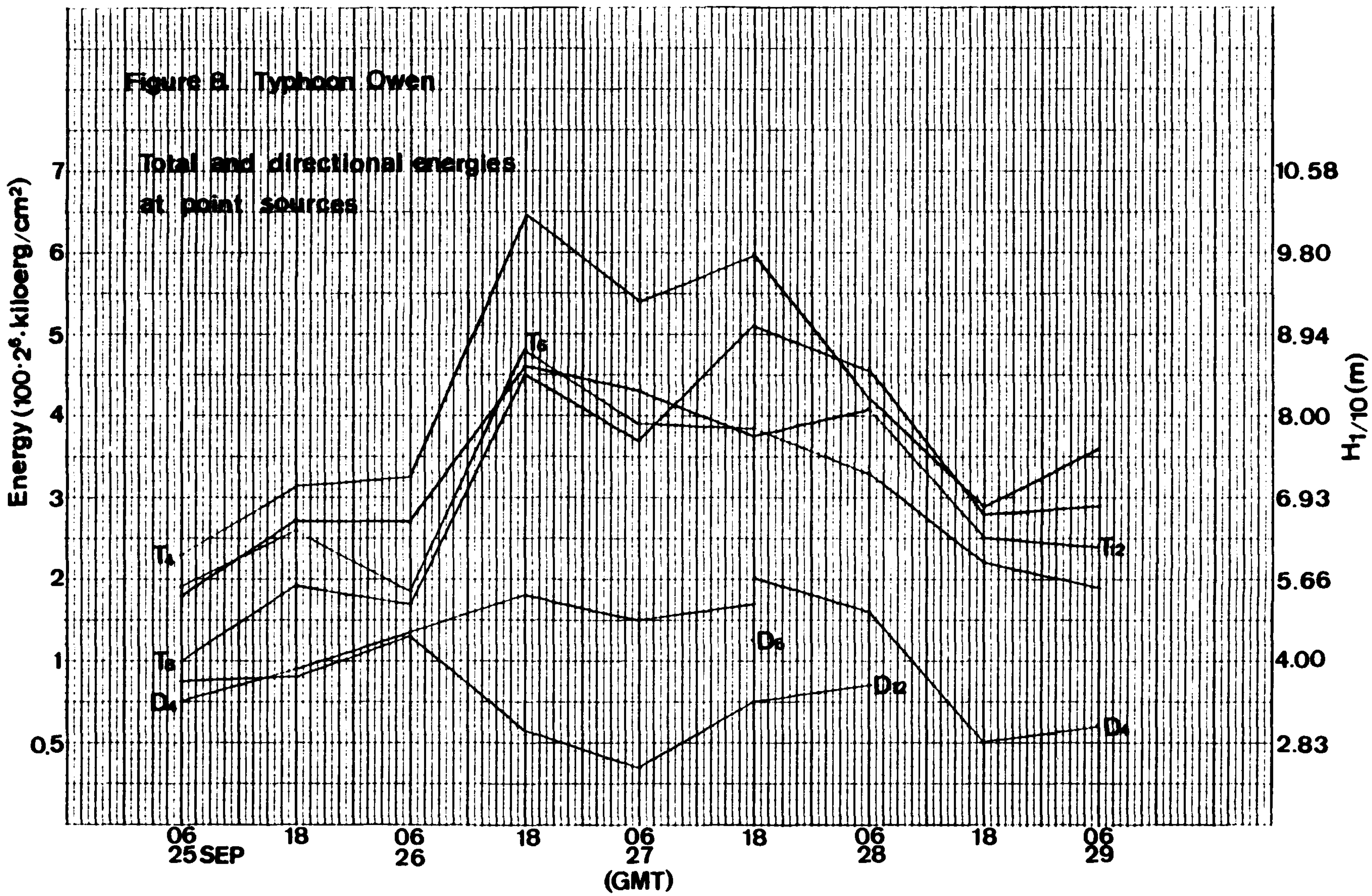


Figure 8. Typhoon Owen

Total and directional energies at point sources

III. PREDICTION OF SWELL CHARACTERISTICS

The periods of high waves due to typhoons are usually in the range of 7~19 sec. They travel in deep water with the group corresponding velocities 10~30 kts. It normally necessitates 1~4 days for conspicuous swells generated in a typhoon in the far south seas to reach Cheju-do, Korea.

The group velocities of periods 7 and 10 sec are constant along their paths since they remain in "deep water." But for periods 13, 16 and 19 sec, the group velocities vary because of depth variations. Thus, I considered two distance components: in deep water R_o and in shallow water R for periods 13, 16 and 19 sec.

The travel distances between grid points and observation points are calculated with the assumption of plane geometry. Then, group velocities, travel distances and travel times are derived for each period in this section.

A. THE SETTING OF THE FORECAST SITE AND ITS RELATION TO THE WAVE SOURCES

The passes of the Ryukyu Islands act as windows between the energy sources and the forecast site, Cheju-do, Korea. Since the largest land length for blockage of energy is only about 40 NM, this length is not sufficient to interrupt totally the energy propagation. Thus, as a further simplification, I neglected the effect of the Ryukyu Islands

against the energy propagation. The window is assumed sufficient for total propagation.

B. GROUP VELOCITY

Some simplications are used in assigning group velocity values along the route from typhoons to the observation site.

From linear wave theory group velocity, C_g is given by

$$C_g = \frac{1}{2} [c + \frac{2kh}{\sinh 2kh}] = nc$$

(all the symbols are defined below)

and phase speed c is given by $c = \frac{g}{\sigma} \tanh kh$. In deep water this is well approximated by $c_o = g/\sigma = 3.03$ T (ktc) for T given in seconds, and in shallow by $c = \sqrt{gh}$. But in the general case c varies with both the depth of water and the wavelength.

The classifications "deep" and "shallow" are given in terms of "relative depth h/L_o, described below. Since there is no "shallow water" between the wave sources and Cheju-do, Korea, (corresponding to the periods used by TYWAVES), I will use only the general equation and the deep water approximation. In these equations

C_g = group velocity

c = phase speed (c_o in deep water)

n = the fraction of energy propagated at phase speed

g = gravity acceleration

h = water depth

σ = wave angular frequency ($2\pi/T = 2kf$, where T is period)

k = local wave number ($2\pi/L$, where L is wave length)

f = wave frequency ($1/T$)

It is important to note that c and group velocity, Cg must be found as functions of both h and σ. A straight-forward method is illustrated below, where the dependence on kh is replaced by the deep water wavelength $L_o = 2\pi g/\sigma^2$.

The local wavelength is then found from L/L_o, a function of the relative depth h/L_o.

Since $C/C_o = L/L_o$, the phase speed c can be found from h and σ.

To estimate the group velocity by definition, $C_g = \frac{1}{2} c \left[1 + \frac{2kh}{\sinh kh}\right] = nc$ where, n takes on the following values for corresponding h/L_o:

general case ($\frac{1}{2} \geq h/L_o \geq \frac{1}{20}$): $1>n>\frac{1}{2}$,

deep water case ($h/L_o > \frac{1}{2}$): $n = \frac{1}{2}$.

In order to simplify calculations, I used $n = 3/4$ in the waters between the Ryukyu Islands and Cheju-do where, for the longer periods, the relative depth range $\frac{1}{2} \geq h/L_o \geq \frac{1}{20}$. With this simplication, the corresponding group velocities become the following:

$\bar{T} = 13$ sec; $C_g = 29.4$ kts

$\bar{T} = 16$ sec; $C_g = 33.6$ kts

$\bar{T} = 19$ sec; $C_g = 35.8$ kts

The influence on the calculation of C_g of the use of these representative constant values is discussed in Chapter IV.D.

For deep water

$$C_o = 3.03T \text{ (kts for T in sec)}$$

$$C_{g_o} = nc = \frac{1}{2} C_o = 1.515T \text{ (kts for T in sec)}$$

Therefore, group velicity in knots and depth at which C_g replaces C_{g_o} are shown below:

$\bar{T}$ (sec)	7	10	13	16	19
C_{g_o}/C_g (kts)	10.6/-	15.2/-	18.7/29.6	24.3/33.6	28.8/35.8
$h(\frac{L_o}{2}$ in ft)	126	256	433	656	924

C. TRAVEL DISTANCE AND ARRIVAL TIME

The travel distance between grid points in the storm and the observation point 33.2°N 126.6°E are calculated with the assumptions of plane geometry. Consider this example.

On 12 GMT July 30, the grid point 4 was at 17.4°N133.9°E. Thus, the north-south component is given by

$$y = [\text{lat (site)}^{\circ} - \text{lat (grid point)}^{\circ}] \times 60 \text{ NM}$$

$$= [33.2 - 17.4] \times 60$$

$$= 948 \text{ NM}$$

and the east-west component is approximated by

$$x = [\text{long (grid point)} - \text{long (site)}] \cos(\text{mean lat})] \times 60 \text{ NM}$$

$$= [133.9 - 126.6] \cos(17.4) \times 60 \text{ NM}$$

$$= 418 \text{ NM}$$

Thus, the travel distance, D, is given by

$D = (x^2 + y^2)^{\frac{1}{2}}$ and for grid point 4,

$$D = (418^2 + 948^2)^{\frac{1}{2}} = 1036 \text{ NM}$$

The travel time, t, is given by

$t = \frac{R_o}{C_{g_o}} + \frac{R}{C_g}$, where $R_o + R = D$

R_o = the deep water distance

R = the remaining distance

Therefore, the arrival time, tar of each period band is given by

$tar(\bar{T}) = t_o + t$, where t_o = leaving time from typhoon area

t = travel time

The Figures 9, 10 and 11 show the swell arrival time for each of the three typhoons. Each curve indicates the arrival time of energy from a source at a specified leaving time labeled with various periods (from 7 to 19 sec.).

Appendix C shows the arrival time calculations for each typhoon.

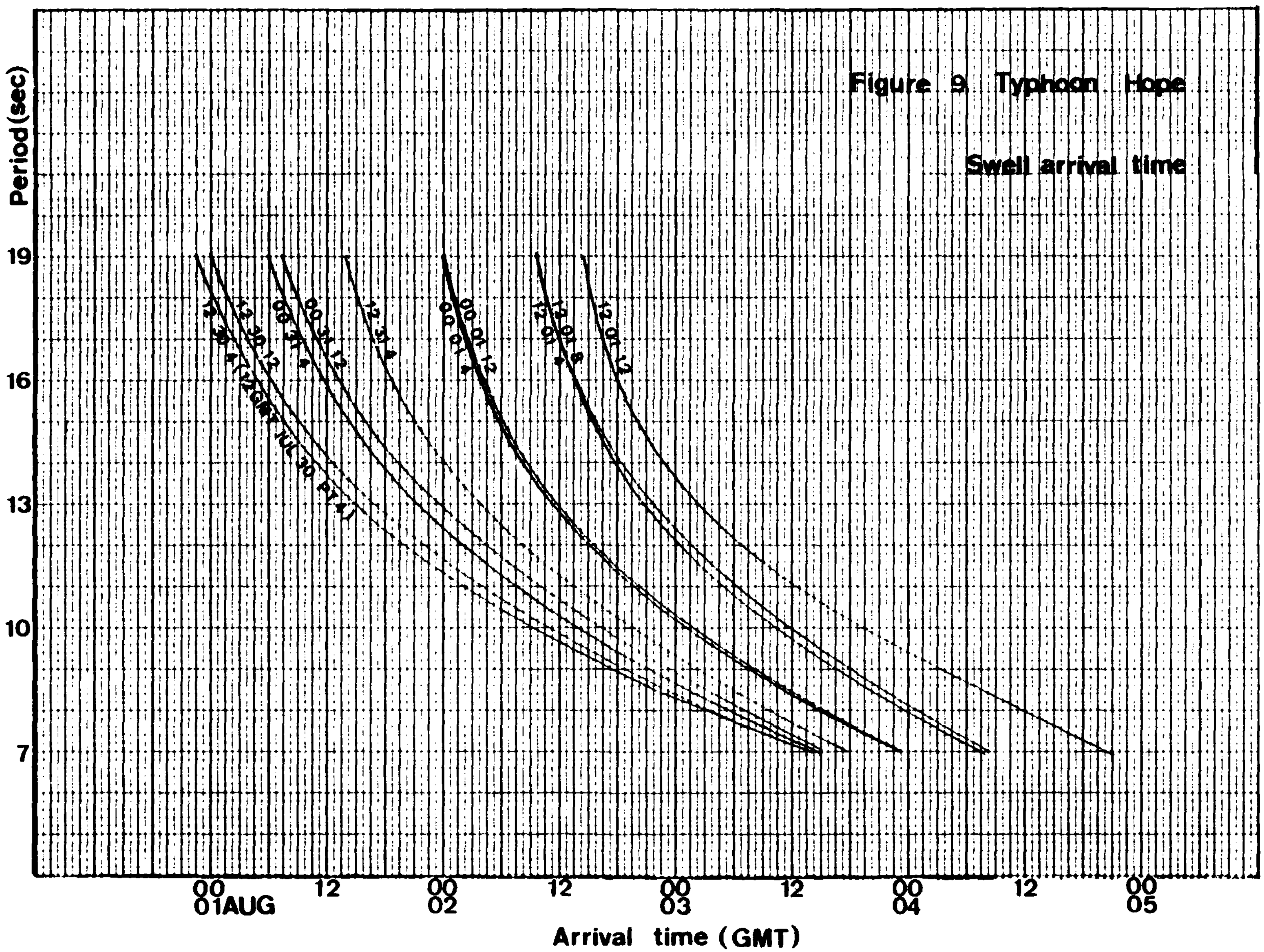


Figure 9. Typhoon Hope
Swell arrival time
Period(sec)
19
16
13
10
7
12 01 12
12 01 8
12 01 4
00 01 12
00 01 4
12 31 4
00 31 12
00 31 4
12 30 12
12 30 4 (12GMT JUL 30 PT 4)
00 01AUG
12
00 02
12
00 03
12
00 04
12
00 05
Arrival time (GMT)

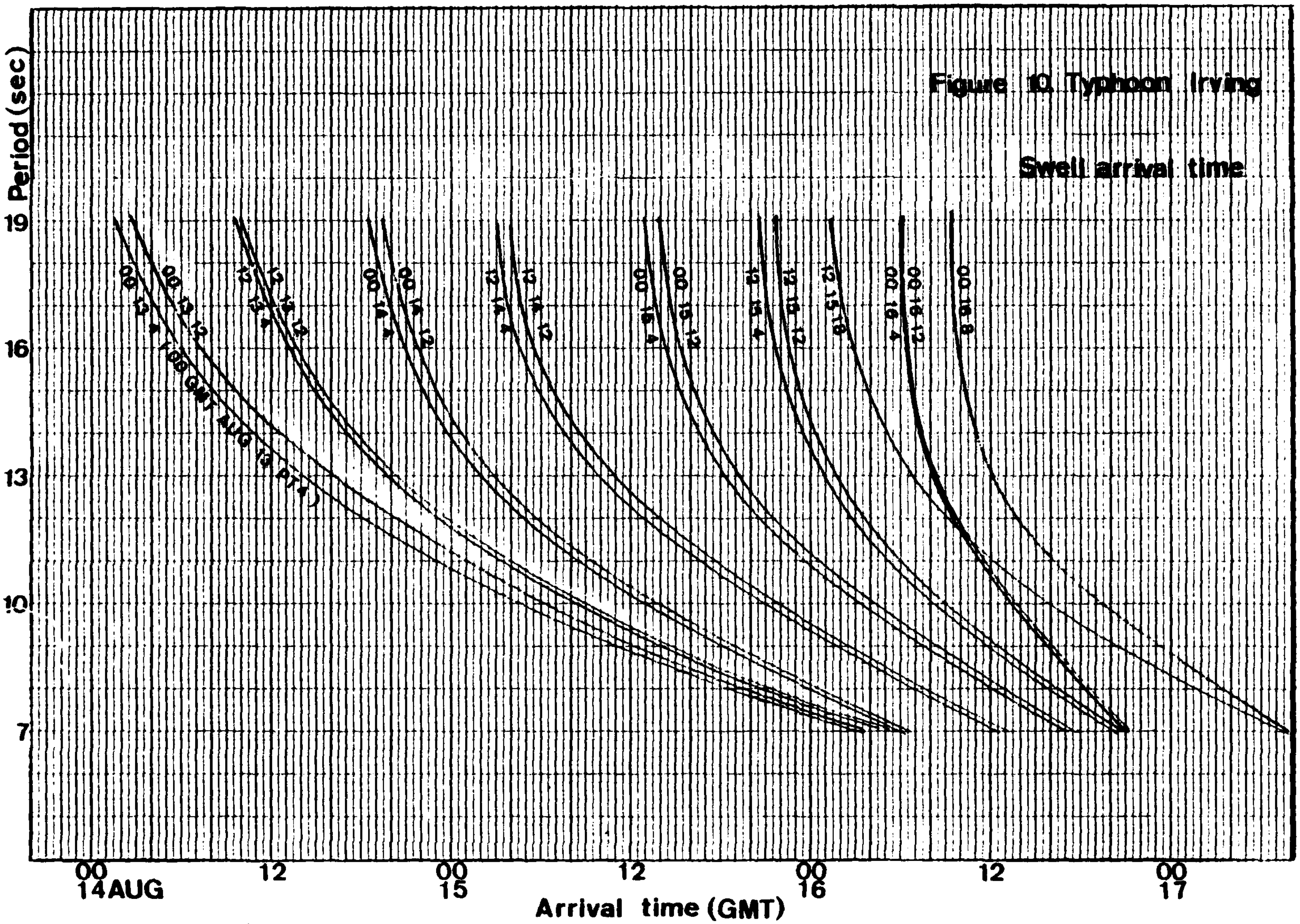


Figure 10. Typhoon Irving

Swell arrival time

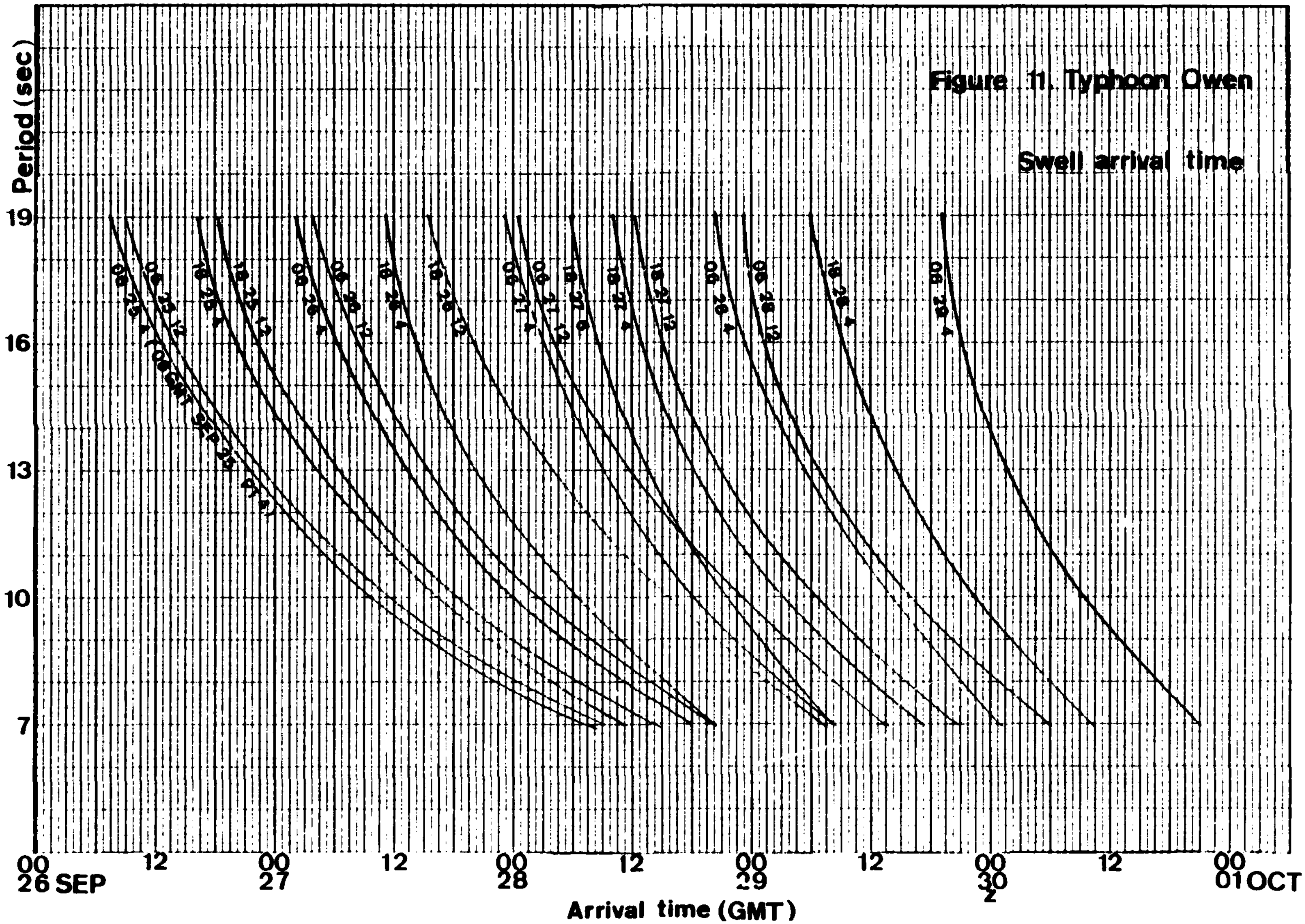


Figure 11. Typhoon Owen

Swell arrival time

IV. THE ENERGY PROPAGATION PROCEDURE

A. PROPAGATION OF SPECTRAL ENERGY COMPONENTS

The spectral forecast permits the forecaster to deal with only that range or periods which have important energy. Each spectral component is tracked with its respective group velocity, only those directions being chosen for which waves can reach Cheju-do. When the typhoon is moving with a velocity component toward Cheju-do, only spectral components with a group velocity greater than the movement of the typhoon are considered (as in Typhoon Irving).

Wave energy generated in a relatively small region at all frequencies will spread over a much larger region as it propagates outward from its source, and the wave characteristics change in such a way as to become more "swell like." There are essentially three processes which contribute to this change in wave characteristics: dispersion and angular spreading, which are modified by shoaling and refraction, and attenuation.

In the procedure followed here, I have ignored attenuation for waves of long period. Dispersion and angular spreading are accounted for by simply following components to Cheju-do with appropriate shoaling and refraction factors.

For ease of calculation shoaling and refraction processes are simplified as described below. As seen on Map 1, a slightly curved contour of 100 fathoms (590 ft) connects the northern tip of Taiwan to the south-western tip of Japan. The slope from 590 ft bottom line to 413 ft (70 fathoms) is very steep. But most bottom topography along the path to Cheju-do, north of the 413 ft bottom contour is almost flat with the depth of 45 fathoms (266 ft) up to the forecast site (33.2°N 126.6°E).

Therefore, I have approximated to underwater topography by assuming only two water depths, a deep water and a shallow water (intermediate water depth) region with an abrupt jump between them.

To compute the wave characteristics at a shoal water site, the shoaling and refraction are considered using the values of C_g and n from Chapter III.B.

The energy of component E_o $(\bar{T},\bar{\theta})$ in the typhoon area (deep water) is transformed after shoaling and refraction to its value at the forecast site according to

$$E(i, j) = E_o\,(i, j)\cdot k_s^2\,(i, j)\;k_r^2\,(i, j)$$

where E (i, j) is the energy of the component of period $\bar{T}_i$ and which had the direction θ_j in the generating area,

and k_s (i, j), k_r (i, j) are the respective shoaling and refraction factors of those components.

Details of calculation of k_s and k_r are given in the following sections. The refraction and shoaling calculations for three typhoons are shown in Appendix D. The following is a sample calculation on 12 GMT July 30 for Typhoon Hope at source point 4.

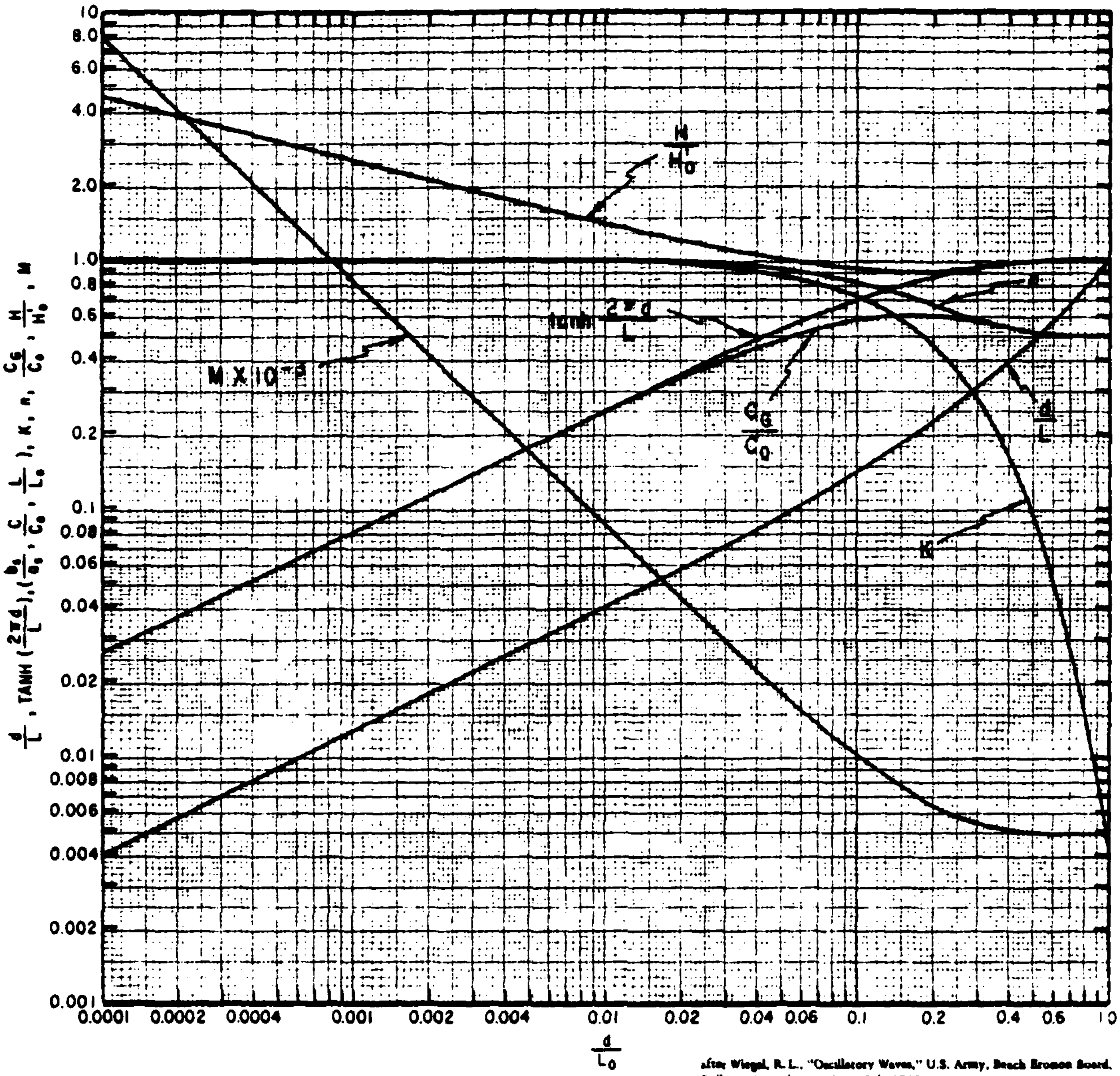
$\bar{T}$	7	10	13	16	19
k_s	1	1	0.92	0.89	0.90
k_r	1	1	1	0.989	0.972
$(k_s\ k_r)^2$	1	1	0.8464	0.7748	0.7653
E_o	7	19	11	9	14
E	7	19	9.3	7.0	10.7

where k_s is derived from plate C-1 [6]
with h = 40 fathoms = 236 ft
k_r is derived from Figure 2-19 [5]
with h = 413 ft and $\alpha_o = 40^o$.

B. SHOALING AND REFRACTION FACTOR

1. Shoaling Factor

The shoaling factor, $k_s = H/H_o'$ was derived from the plate C-1 [6] with depth and period of the appropriate spectral component. The shoal site depth near Cheju-do (33.2^oN 126.6^oE) is 40 fathoms, and the relative depth h/L_o and shoaling factor of each period are shown below.



after Wiegel, R. L., "Oscillatory Waves," U.S. Army, Beach Erosion Board, Bulletin, Special Issue No. 1, July 1948.

Plate C-1. Illustration of Various Functions of $\frac{d}{L_o}$

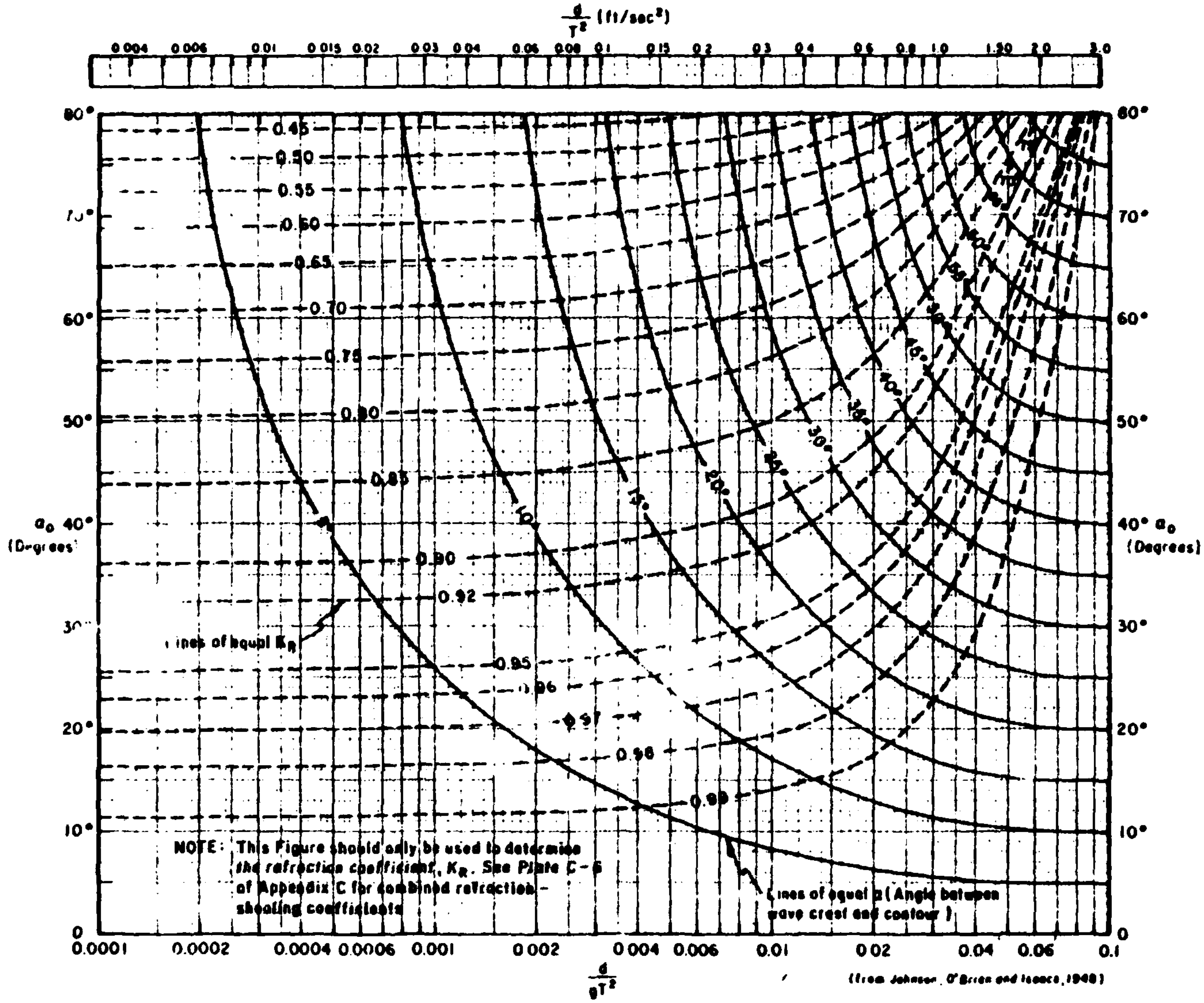


Figure 2-19 Changes in Wave Direction and Height Due to Refraction on Slopes with Straight, Parallel Depth Contours

$\bar{T}$	17	10	13	16	19
h/L_o	0.94	0.46	0.24	0.18	0.13
k_s	1	1	0.92	0.89	0.90

2. <u>Refraction Factor</u>

Generally, two basic techniques of refraction analysis are available--graphical and numerical. Several graphical procedures are available, but all methods of refraction analyses are based upon Snell's law. Refraction may be treated analytically in any region with straight and parallel contours, by using Snell's law directly: $\sin \alpha = (\frac{c}{c_o}) \sin \alpha_o$, where α is the angle between the wave crest and the bottom contour, and α_o is the angle between the deep water wave crest and the bottom contour.

Figure 2-19 [5] shows the relationships among α, α_o, period, depth and refraction factor in graphical form. I derived the refraction factor from using this graph, Figure 2-19, the bottom contour and period. Also, I assumed that the refraction factor is 1 if the angle α_o (between crest and bottom contour) is less than 10^o and that the refraction occurs only one time at the depth of maximum bottom gradient where waves are refracted because of the wide flat-bottomed portions over most of the intermediate water propagation path as seen on Map 1.

With these considerations, I derived the refraction factor and predicted the shoaling energy. Those procedures are shown in Appendix D.

C. SHOALING AND REFRACTION OF THE SPECTRAL COMPONENTS

Each deep water wave spectral component derived from the TYWAVES model moves with its respective group velocity. I considered the 80 energy components to behave as monochromatic component waves. To assess the shoaling and refraction of each to the shoal-water site I assumed that the wave power transmitted between a given pair of orthogonals remains constant at all depths (this means no frictional losses, diffraction or scattering, and also implies that a steady state exists).

With these assumptions the wave power P is given by

$$P = E\ C_g\ b = E_o\ C_{g_o}\ b_o$$

$$\text{Thus, } E = E_o \frac{C_{g_o}\ b_o}{C_g\ b} = E_o \times k_s^2\ k_r^2 = \frac{1}{8}\ PgH^2$$

where E = the average wave energy per unit area of sea surface for waves transformed by shoaling and refraction.

P = water density

g = acceleration of gravity

H = wave height of transformed waves

C_{g_o}, C_g = group velocity

b_o, b = orthogonal separations

k_s = shoaling factor

k_r = refraction factor

The energy in each spectral component of the swell at the observation site was calculated by modifying the energy spectrum at the selected sources for the effects of shoaling and refraction according to equation $E = E_o \cdot k_s^2 \cdot k_r^2$.

The energy associated with the various components as a function of time of arrival at observation site, as seen in Figures 9, 10 and 11.

The total energy in the swell at any given arrival time is estimated by summing all the shoaling components at that time.

In summary, each component in typhoon area's $\bar{T} - \theta$ spectrum is shoaled and refracted using the k_s and k_r values appropriate to it to find the energy at the observation site.

1. Shoaling **Process** (Computation)

   See Appendix D.

2. Shoaling Energy Components From Each Source Versus Arrival Time

   As seen in Figures 12, 14 and 16, the energy of the components from all sources is shown as a function of its arrival time at Cheju. See Appendix D.

3. The Predicted Swell Waves at Prediction Site

As shown in Figures 13, 15 and 17, the predicted swell waves are the sum of all transformed components at given time at the forecast site.

For Typhoon Irving (see Figure 15) beginning 12 GMT August 16, the forecast site is already inside typhoon area. Therefore, there is no prediction done after that time. These predictions are discussed in Chapter IV.D.

D. THE OBSERVED DATA

Observations of wave conditions for verification of the swell forecasts were obtained from the sources, the National Oceanographic Data Center (NODC) and the Republic of Korea (ROK) Navy. All listed heights are based on visual estimates.

Following Table VIII shows the visual observation of swell heights (H 1/10) for each typhoon. The data from NODC are sparse and often far from the forecast site, but they appear to be samples from the same set as those of the ROK Navy. The data from ROK Navy visual observations were made at 33.2°N, 126.5°E close to my point of interest (33.2°N, 126.6°E). So I considered this point exactly the same as my forecast site.

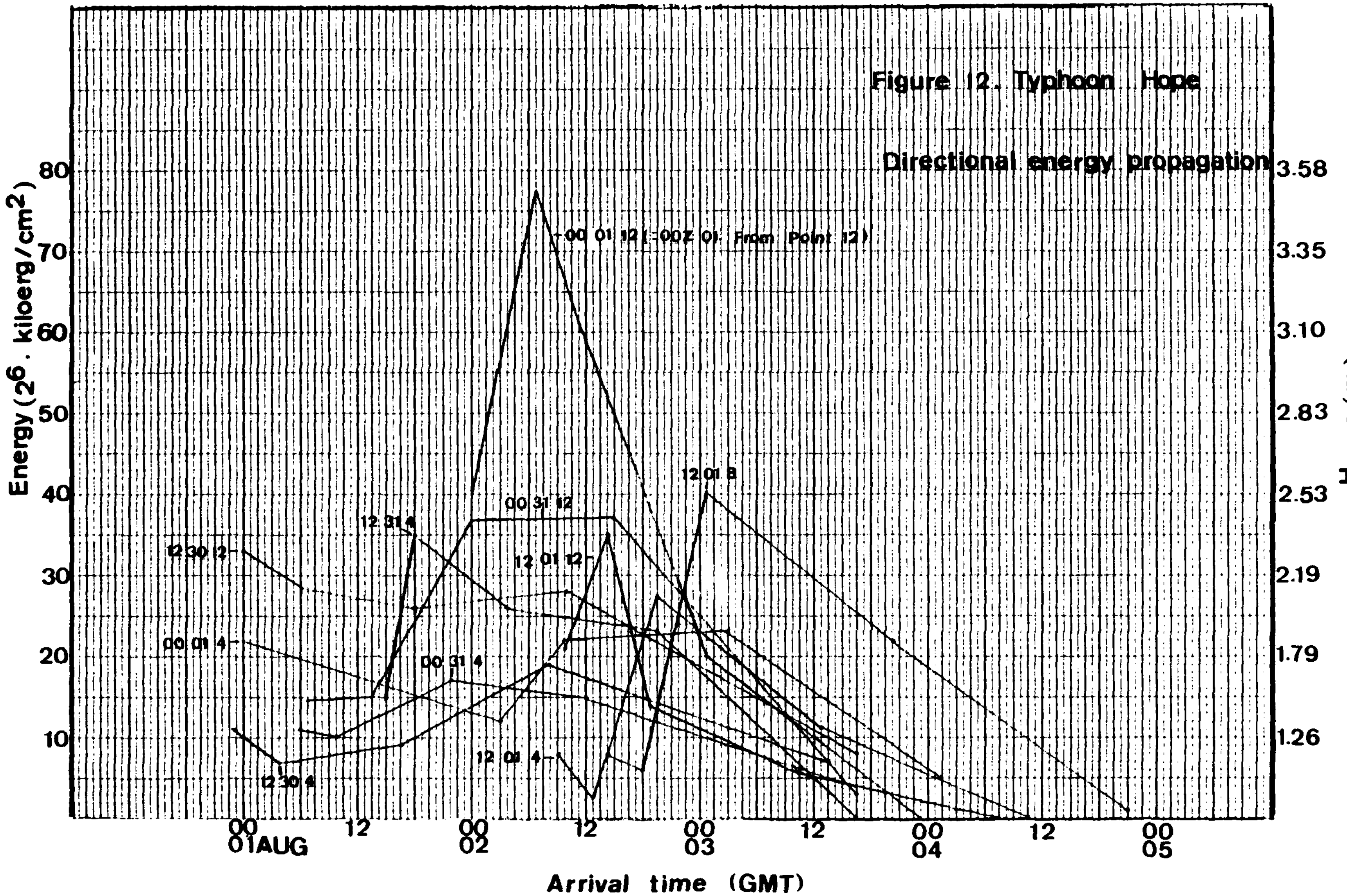


Figure 12. Typhoon Hope

Directional energy propagation

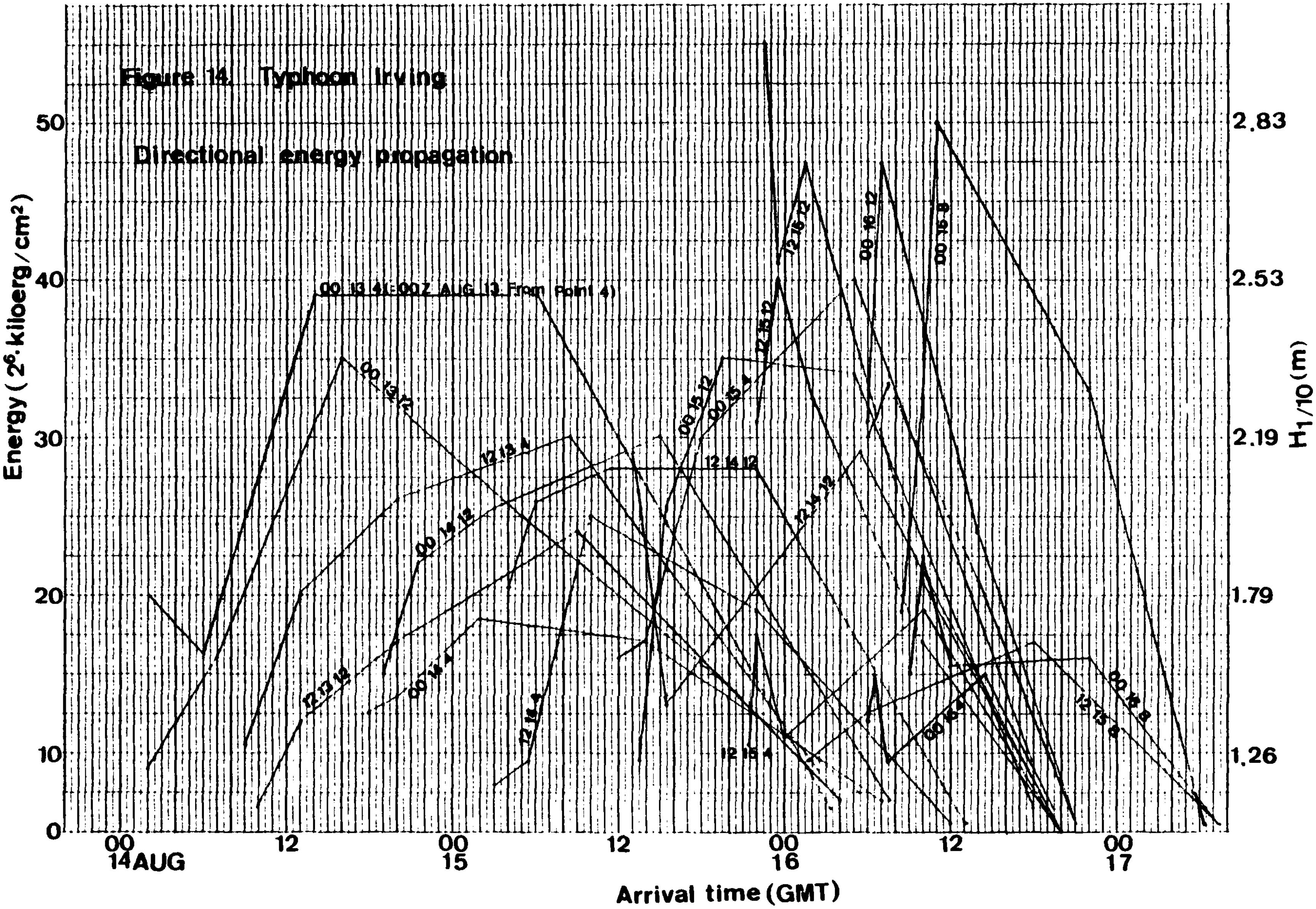


Figure 14. Typhoon Irving

Directional energy propagation

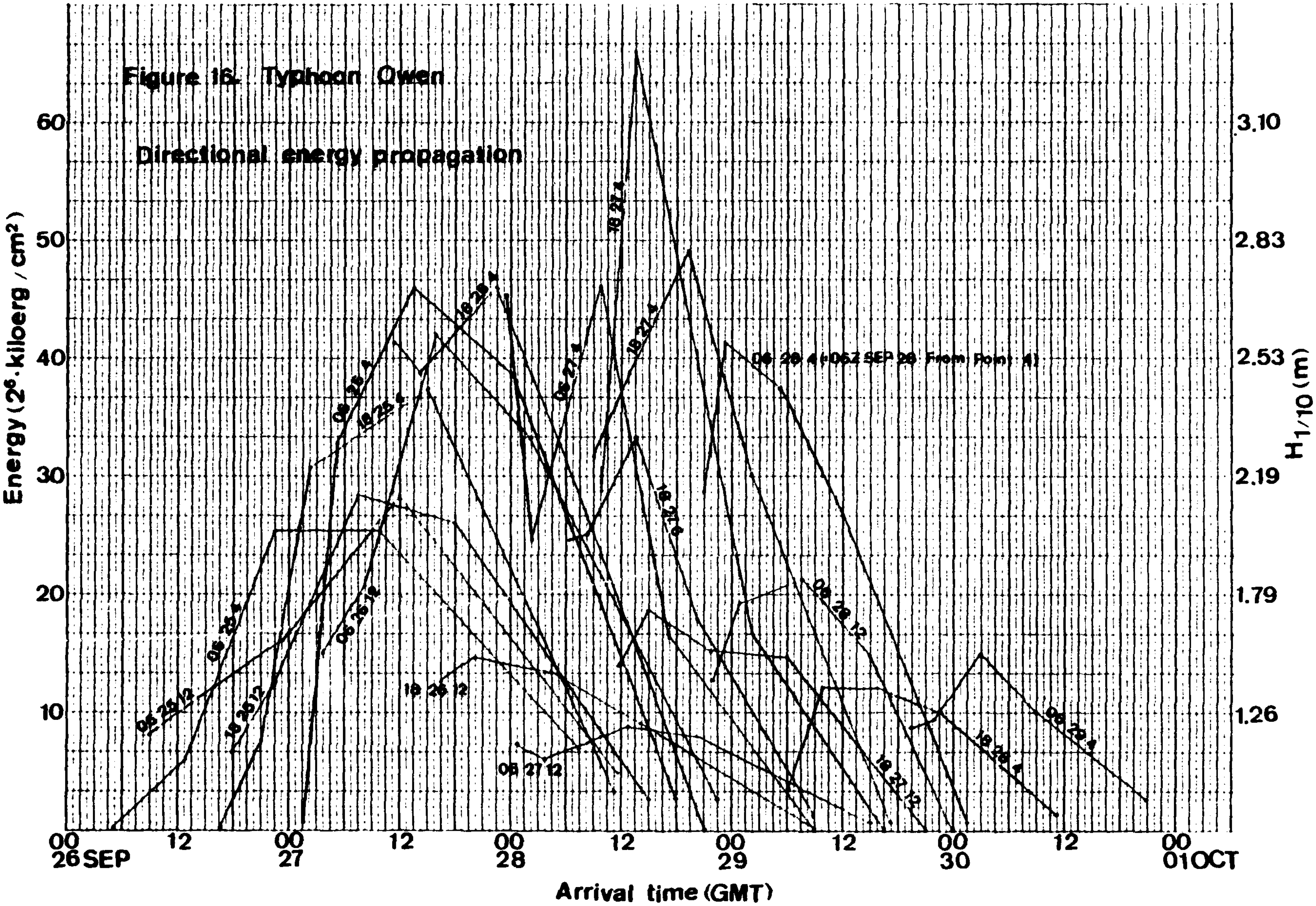


Figure 16. Typhoon Owen

Directional energy propagation

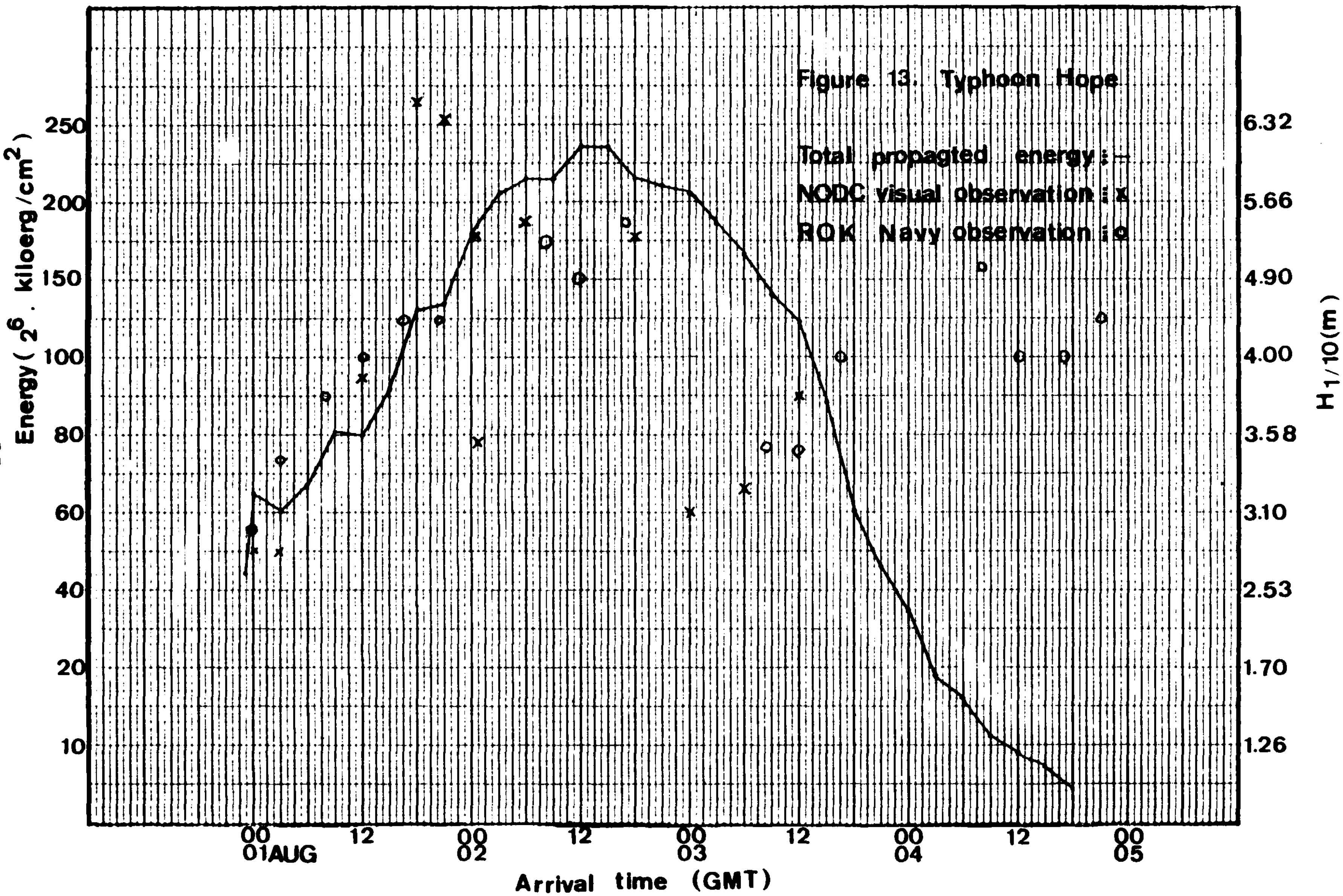


Figure 13. Typhoon Hope

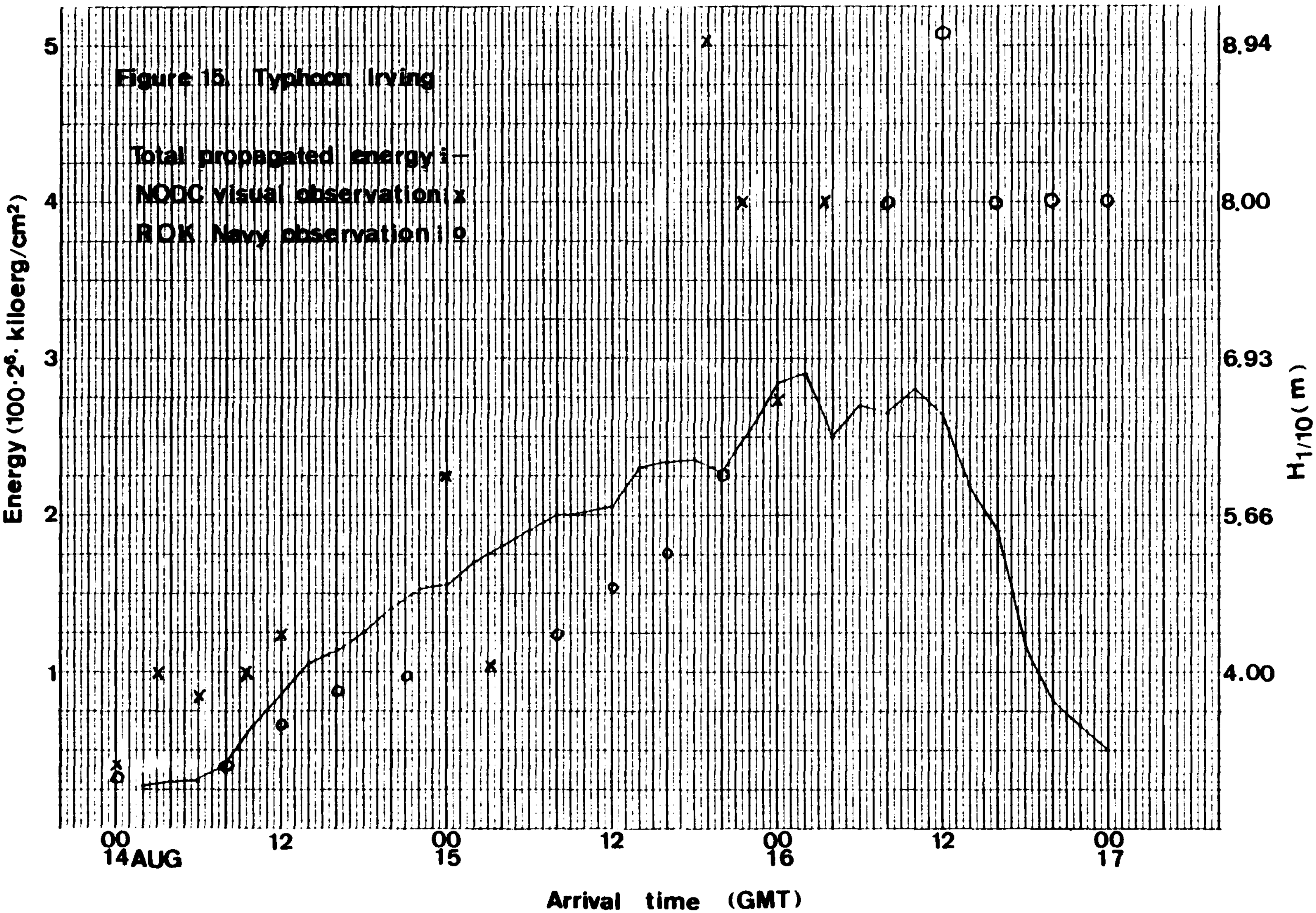


Figure 15. Typhoon Irving
Total propagated energy : —
NODC visual observation : x
ROK Navy observation : o
Energy (100·2⁶· kiloerg/cm²)
5
4
3
2
1
$H_{1/10}$ (m)
8.94
8.00
6.93
5.66
4.00
00
14AUG
12
00
15
12
00
16
12
00
17
Arrival time (GMT)

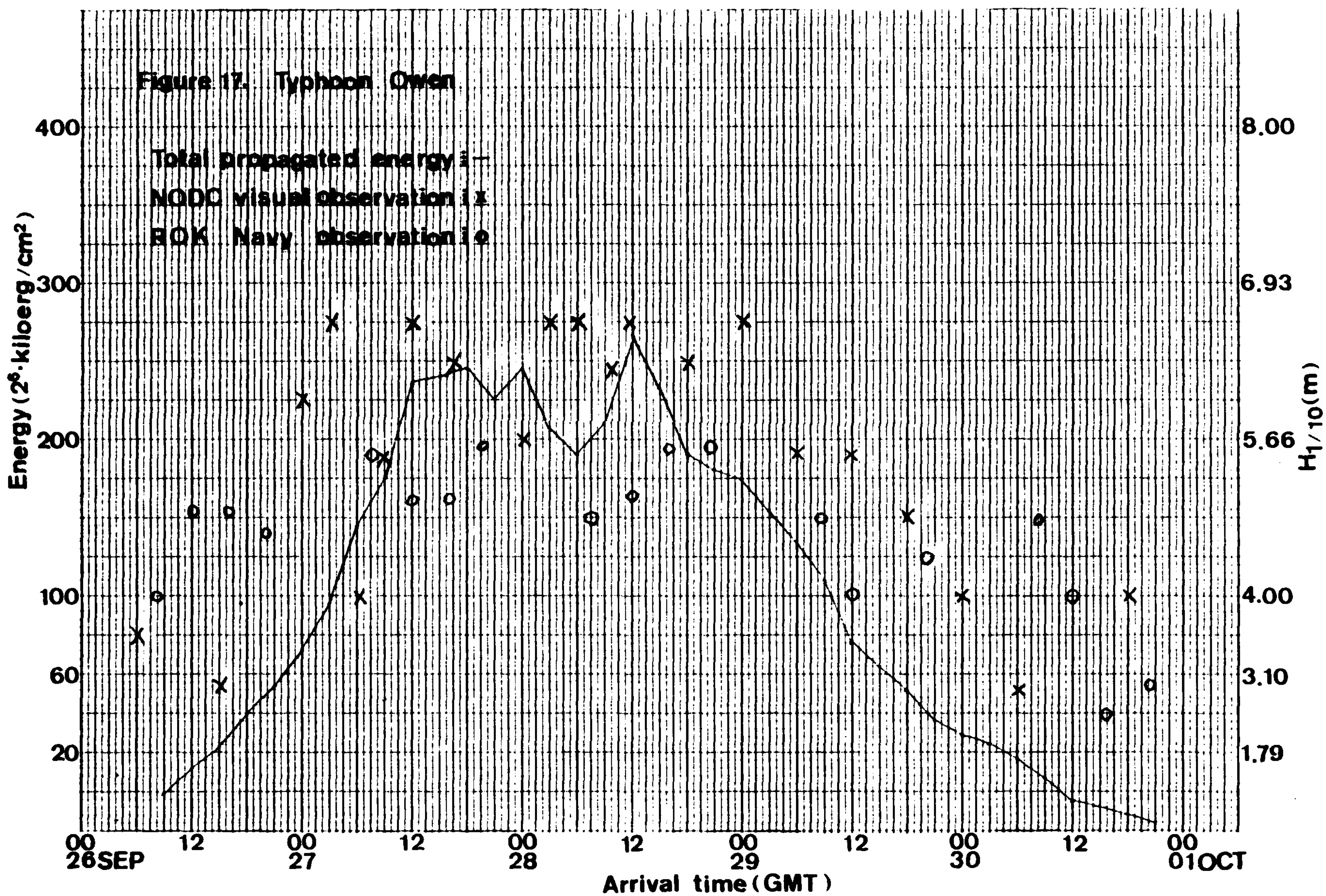


Figure 17. Typhoon Owen
Total propagated energy : —
NODC visual observation : x
ROK Navy observation : o
Energy (2^6·kiloerg/cm^2)
400
300
200
100
60
20
$H_{1/10}$(m)
8.00
6.93
5.66
4.00
3.10
1.79
00 26SEP
12
00 27
12
00 28
12
00 29
12
00 30
12
00 01OCT
Arrival time (GMT)

TABLE 8

The Visual Observation Data by NODC and ROK Navy

1. For Typhoon Hope

DTG (GMT)	Location (^{o}N-^{o}E)	H 1/10 (meters)	Source
79080100	33.6-125.2	2.5	NODC
0104	32.3-126.0	2.5	NODC
0112	31.2-126.7	4.0	NODC
0118	27.7-124.6	6.5	NODC
0121	27.8-125.4	6.5	NODC
0200	29.1-128.0	6.5	NODC
0206	28.0-129.0	5.5	NODC
0218	26.9-125.8	5.0	NODC
0300	28.7-128.6	3.0	NODC
0306	31.4-126.2	3.0	NODC
0312	32.3-125.9	3.5	NODC
080100	33.2-126.5	3.0	ROK Navy
0104	33.2-126.5	3.5	ROK Navy
0108	33.2-126.5	3.7	ROK Navy
0112	33.2-126.5	4.0	ROK Navy
0116	33.2-126.5	4.5	ROK Navy
0120	33.2-126.5	4.5	ROK Navy
0208	33.2-126.5	5.0	ROK Navy
0212	33.2-126.5	4.5	ROK Navy
0216	33.2-126.5	5.5	ROK Navy
0220	33.2-126.5	4.5	ROK Navy
0308	33.2-126.5	3.5	ROK Navy
0312	33.2-126.5	3.5	ROK Navy
0316	33.2-126.5	3.0	ROK Navy
0320	33.2-126.5	5.0	ROK Navy
0408	33.2-126.5	4.0	ROK Navy
0412	33.2-126.5	3.0	ROK Navy
0416	33.2-126.5	3.0	ROK Navy
0420	33.2-126.5	2.5	ROK Navy

2. <u>For Typhoon Irving</u>

DTG (GMT)	Location (^{o}N-^{o}E)	H 1/10 (meters)	Source
79081400	29.10127.6	2.5	NODC
1403	28.5-127.6	4.0	NODC
1406	28.7-129.3	3.5	NODC
1409	27.7-129.7	4.0	NODC
1412	29.2-131.1	4.5	NODC
1500	30.0-125.0	6.0	NODC
1503	30.7-127.3	4.0	NODC
1515	28.3-130.3	8.0	NODC
1518	27.2-130.0	9.0	NODC
1521	26.5-128.8	8.0	NODC
1600	27.1-130.0	6.5	NODC
1603	27.3-128.5	8.0	NODC
1606	29.6-129.2	5.5	NODC
1700	27.4-125.5	6.0	NODC
79081400	33.2-126.5	2.5	ROK Navy
1408	33.2-126.5	2.5	ROK Navy
1412	33.2-126.5	3.0	ROK Navy
1416	33.2-126.5	3.5	ROK Navy
1420	33.2-126.5	3.5	ROK Navy
1508	33.2-126.5	4.0	ROK Navy
1512	33.2-126.5	4.5	ROK Navy
1516	33.2-126.5	5.0	ROK Navy
1520	33.2-126.5	6.0	ROK Navy
1608	33.2-126.5	8.0	ROK Navy
1612	33.2-126.5	9.0	ROK Navy
1616	33.2-126.5	8.0	ROK Navy
1620	33.2-126.5	8.0	ROK Navy
1708	33.2-126.5	8.0	ROK Navy
1712	33.2-126.5	9.0	ROK Navy
1716	33.2-126.5	8.0	ROK Navy
1720	33.2-126.5	7.0	ROK Navy

3. For Typhoon Owen

DTG (GMT)	Location (^{o}N-^{o}E)	H 1/10 (meters)	Source
79092600	31.4-128.0	4.0	NODC
2606	33.6-129.1	3.5	NODC
2615	31.8-129.5	3.0	NODC
2700	28.1-126.9	6.0	NODC
2703	27.1-126.6	6.5	NODC
2706	32.6-125.7	4.0	NODC
2709	31.6-125.7	5.5	NODC
2712	30.7-129.8	6.5	NODC
2715	28.7-125.3	6.0	NODC
2800	32.8-128.3	5.5	NODC
2803	30.6-125.7	6.5	NODC
2806	31.5-126.8	6.5	NODC
2809	31.6-126.6	6.0	NODC
2812	31.7-126.6	6.5	NODC
2818	34.0-128.3	6.0	NODC
2900	32.7-127.7	6.5	NODC
2606	32.1-127.3	5.5	NODC
2912	31.0-126.4	5.5	NODC
2918	34.0-129.7	5.0	NODC
3000	29.0-124.7	4.0	NODC
3006	30.8-127.7	3.0	NODC
3018	30.4-131.6	4.0	NODC
79092600	33.2-126.5	2.5	ROK Navy
2608	33.2-126.5	4.0	ROK Navy
2612	33.2-126.5	5.0	ROK Navy
2616	33.2-126.5	5.0	ROK Navy
2620	33.2-126.5	4.5	ROK Navy
2708	33.2-126.5	5.5	ROK Navy
2712	33.2-126.5	5.0	ROK Navy
2716	33.2-126.5	5.0	ROK Navy
2720	33.2-126.5	5.5	ROK Navy
2808	33.2-126.5	4.5	ROK Navy
2812	33.2-126.5	5.0	ROK Navy
2816	33.2-126.5	5.5	ROK Navy
2820	33.2-126.5	5.5	ROK Navy
2908	33.2-126.5	4.5	ROK Navy
2912	33.2-126.5	4.0	ROK Navy
2916	33.2-126.5	4.5	ROK Navy
2920	33.2-126.5	4.5	ROK Navy
3008	33.2-126.5	5.0	ROK Navy
3012	33.2-126.5	4.0	ROK Navy
3016	33.2-126.5	2.5	ROK Navy
3020	33.2-126.5	3.0	ROK Navy

E. COMPARISON OF SWELL PREDICTIONS AND OBSERVATIONS

The predicted and observed heights are plotted in Figures 13, 15 and 17, and are good agreement. Detailed comparisons for each typhoon follow:

1. Typhoon Hope

The first predicted swell arrival times from each of three sources, and the NODC and ROK Navy observations are almost the same with similar energies (see Figure 13).

The peak energy arrival times are also nearly the same, but the peak predicted energy is slightly higher than the observations. This is reasonable agreement since it is estimated that the visual observations can be error. Verploegh 1961 [18] estimated the average observational error for a visual observation of wave height varies from 1 ft at 5 ft wave heights to 3 ft at 18 ft wave heights.

2. Typhoon Irving

As seen in Figure 15, the predicted swell arrival time nearly matches the time shown by both sets of observations. However, the predicted energy of the rise is slightly higher than the observational values. The peak energy (around the time of 20 GMT August 15) is also the same as the observational peak.

After 00 GMT August 16, the prediction site is within the typhoon's wind circulation area. Most wave heights (H 1/10) are 8m and the highest observation is 10m. These waves

dominate the entire wave field and no swell can be distinguished later than 00 GMT August 16.

3. Typhoon Owen

In Typhoon Owen (see Figure 17), the swell arrival time indicated by observations is earlier than the predicted time by about 6~12 hours. The predicted peak energy lies close to the observational values.

In fact, the NODC values are higher than those of the prediction, and ROK Navy observations are lower. Except near the peak both observation sets show similar time variations. Therefore, the observed values are considered consistent and probably accurate.

F. ERROR SOURCES

I have made several assumptions in this study in order to simplify calculations. The most serious error sources involve assumptions about the windows in the Ryukyu Islands, group velocity in shallow water, and simple bottom contours in shallow water.

There are also differences between the predictions (which include waves dependent on the local weather conditions) that make it difficult to evaluate the prediction. Regarding the assumptions about group velocity in Chapter III.B, I used $n = 3/4$ in shallow water for calculation of group velocity $C_g = nc$. In Typhoon Hope, which has the longest shallow water travel distance, miscalculation of C_g would have its

greatest effect. Yet the observed and predicted energy peaks are not greatly separated. This may mean that the approximations are realistic.

The bottom contour assumptions seem to be reasonable through three tests. The local weather condition is the most serious factor contributing to differences between the observations and the predictions. The local wind pattern was the following at Cheju-do, according to the ROK Navy data set.

1979	072900-073100:	SW 5-8 kts (preceding Hope swell)
	080100-080300:	SW 6-10 kts (during Hope swell)
1979	081200-081300:	S 6-8 kts (preceding Irving swell)
	081400-081700:	S 30-60 kts (during Irving swell)
	092400-092600:	E 5-8 kts (preceding Owen swell)
	092600-093000:	E 20-30 kts (during Owen swell)

Therefore, before the swell arrivals, the local wave heights were considered less than 1~1.5 m. During Irving and Owen there were important local sea contributions to observed height.

Lastly, the original error sources, i.e., those involving input parameters for the TYWAVES model, the location of the typhoon center, the winds in the source region, and typhoon

size, etc., are ignored in this study. Those errors are discussed in Refs. [2] and [17].

V. CONCLUSIONS

From Figures 13, 15 and 17, I can conclude that most predicted swell heights are lower than those of the observations (combined sea and swell).

The times of occurrence of the predicted peak heights agreed reasonably well with those of observations for the swell from each typhoon.

These results on the basis of this limited test suggest that TYWAVES predict satisfactorily those swells in the East China Sea which originate in tropical cyclones in the western North Pacific.

Computer aided predictions may improve the quality of the forecasts by reducing the need for simplifying approximations, as in the case of the treatment in this thesis of the shoaling and refraction processes. Such predictions would also provide a larger base for assessing the accuracy of the method. Additional verification is required to draw more specific conclusions.

APPENDIX A

Outputs of TYWAVES For Typhoon Owen at 12 GMT September 26

The following tables and figures show the computer analysis for Typhoon Owen by TYWAVES.

a. Period-directional spectrum at each of 12 sources.

b-1. The significant wave height (H 1/3 in feet) distribution in typhoon area. "O" indicates the land area and the distance between the grid points is 40 NM.

b-2. The maximum wave period distribution in typhoon area. "-1" indicates the land area.

b-3. The maximum wind wave directions distribution. The direction indicated with 16 unit point rose, from North (1) to NNE (16) with CCW direction.

c. NEPRF Typhoon Wave Program Analysis for Typhoon Owen during the typhoon period from the time of the first typhoon warning to 72 hours later, based on post-analysis data.

s. Period-directional spectrum at each of 12 sources.

TYPHOON WAVES POINT 1

H.1/10 = 7.4 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	* 0	0	[illegible]	0	0	0
NNE	0	* [illegible]	0		0	0	0
NE	46	* 0	1	11	11	10	11
ENE	104	* 0	2	19	31	12	39
E	152	* 0	2	32	37	51	27
ESE	35	* 0	0	5	14	0	14
SE	7	* 0	0	[illegible]	2	0	0
SSE	[illegible]	* 0	0		0	0	0
S	0	* 0	0	[illegible]	0	0	0
SSW	[illegible]	* 0	[illegible]		0	0	0
SW	[illegible]	* [illegible]	[illegible]		[illegible]	0	0
WSW	[illegible]	* [illegible]	[illegible]		0	0	0
W	0	* 0	0		0	0	0
WNW		* [illegible]	[illegible]		0	[illegible]	0
NW	[illegible]	* [illegible]	[illegible]		[illegible]	[illegible]	0
NNW	[illegible]	* 0	0		[illegible]	0	0
TOTAL	346	0	7	74	97	75	92
	PERIODS	4	7	1	13	16	19

TYPHOON WAVES POINT 2

H.1/10= 8.0 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	* 0	0	0	0	0	0
NNE	0	* 0	0	0	0	0	0
NE	0	* 0	0	0	0	0	0
ENE	0	* 0	0	0	0	0	0
E	0	* 0	0	0	0	0	0
ESE	0	* 0	0	0	0	0	0
SE	0	* 0	0	0	0	0	0
SSE	0	* 0	0	0	0	0	0
S	0	* 0	0	0	0	0	0
SSW	0	* 0	0	0	0	0	0
SW	25	* 0	1	8	2	0	12
WSW	89	* 0	3	14	29	1	40
W	187	* 0	3	39	53	62	28
WNW	86	* 0	2	11	27	14	29
NW	17	* 0	1	5	5	3	6
NNW	0	* 0	0	0	0	0	0
TOTAL	406	0	12	80	117	77	117
	PERIODS	4	7	10	13	16	19

TYPHOON WAVES POINT 3

H.1/10= 6.1 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	107	* 0	7	34	32	26	4
NNE	53	* 0	5	10	14	0	23
NE	8	* 0	1	2	1	0	2
ENE	0	* 0	0	0	0	0	0
E	0	* 0	0	0	0	0	0
ESE	0	* 0	0	[illegible]	0	[illegible]	0
SE	0	* 0	0	0	0	[illegible]	0
SSE	0	* 0	0	0	0	[illegible]	0
S	0	* 0	0	0	0	[illegible]	0
SSW	0	* 0	0	0	0	[illegible]	0
SW	0	* 0	0	0	0	[illegible]	0
WSW	0	* 0	0	0	0	[illegible]	0
W	[illegible]	* [illegible]	[illegible]	0	0	[illegible]	0
WNW	0	* [illegible]	0	0	0	0	0
NW	24	* 0	2	10	5	[illegible]	3
NNW	68	* 0	7	15	17	4	23
TOTAL	239	0	24	74	71	32	57
	PERIODS	4	7	10	13	16	19

TYPHOON WAVES POINT 4

H.1/10 = 9.7 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N		* [illegible]			0	[illegible]	0
NNE		*	[illegible]		[illegible]	[illegible]	0
NE		*	[illegible]		[illegible]	[illegible]	0
ENE	[illegible]	*			[illegible]		[illegible]
E	[illegible]	* [illegible]					[illegible]
ESE	2	*	[illegible]		0	2	[illegible]
SE	24	* 0	1	7	7	[illegible]	12
SSE	131	* [illegible]		12	38	31	48
S	176	*	[illegible]	29	48	69	27
SSW	112	* [illegible]	[illegible]	14	[illegible]		56
SW	24	* [illegible]	[illegible]	7	6	[illegible]	14
WSW		* [illegible]					[illegible]
W	[illegible]	*	[illegible]		[illegible]		[illegible]
WNW		*	[illegible]		[illegible]		[illegible]
NW		* [illegible]			[illegible]		[illegible]
NNW	[illegible]	*			[illegible]		[illegible]
TOTAL	4[illegible]	0	3	7[illegible]	1[illegible]1	[illegible]2	1[illegible]
	PERIODS	4	7	1	13	16	19

TYPHOON WAVES POINT 5

H.1/10= 5.4 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	15	* 0	1	6	4	2	0
NNE	56	* 0	3	26	14	9	2
NE	97	* 0	3	24	34	23	11
ENE	15	* 0	1	7	2	4	0
E	0	* 0	0	0	0	0	0
ESE	[illegible]	* 0	[illegible]	0	0	0	0
SE	[illegible]	* 0	[illegible]	0	[illegible]	0	0
SSE		* 0	0	0	0	0	[illegible]
S	[illegible]	* 0	0	0	0	0	0
SSW	[illegible]	* 0	[illegible]	0	0	[illegible]	0
SW	[illegible]	* 0		0	0	0	[illegible]
WSW	[illegible]	* 0		[illegible]	[illegible]	0	0
W	[illegible]	* 0	[illegible]	0	0	0	0
WNW	[illegible]	* 0	[illegible]	0	0	0	0
NW	[illegible]	* 0	[illegible]	0	[illegible]	0	[illegible]
NNW	[illegible]	* 0	0	0	0	0	0
TOTAL	183	0	[illegible]	65	55	40	13
	PERIODS	4	7	10	13	16	19

TYPHOON WAVES POINT 6

H.1/10= 6.9 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	* 0	[illegible]	0	[illegible]	[illegible]	[illegible]
NNE	[illegible]	* [illegible]	0	[illegible]	[illegible]	[illegible]	0
NE	[illegible]	*	[illegible]	0	[illegible]	[illegible]	0
ENE	[illegible]	* [illegible]	[illegible]	0	0	0	0
E	21	* [illegible]	0	7	7	6	0
ESE	87	* [illegible]	1	24	21	30	9
SE	151	*	1	20	48	54	26
SSE	23	*	0	7	6	12	2
S	[illegible]	* [illegible]	0	0	0		0
SSW	[illegible]	*	[illegible]	[illegible]	0	[illegible]	[illegible]
SW		* [illegible]	0	[illegible]	0	[illegible]	[illegible]
WSW		*	[illegible]	[illegible]	0	[illegible]	0
W	[illegible]	* [illegible]	[illegible]	0	0		0
WNW		* [illegible]		[illegible]	0		0
NW	[illegible]	* [illegible]	[illegible]		[illegible]	[illegible]	0
NNW	[illegible]	*	0	0	[illegible]	[illegible]	0
TOTAL	29[illegible]		4	60	83	102	39
	PERIODS	4	7	10	13	16	19

TYPHOON WAVES POINT 7

H.1/1 = 5.9 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	1 *	[illegible]	[illegible]	[illegible]	[illegible]	0
NNE	[illegible] *	[illegible]	[illegible]	[illegible]	[illegible]	0
NE	[illegible] *	[illegible]	[illegible]	[illegible]	[illegible]	0
ENE	[illegible] *	[illegible]	[illegible]	[illegible]	[illegible]	0
E	0 *	[illegible]	[illegible]	0	[illegible]	0
ESE	0 *	0	0	0	[illegible]	0
SE	[illegible] *	[illegible]	[illegible]	[illegible]	[illegible]	0
SSE	[illegible] *	[illegible]	[illegible]	0	[illegible]	0
S	[illegible] *	[illegible]	0	0	[illegible]	0
SSW	[illegible] *	0	0	0	[illegible]	0
SW	[illegible] *	0	0	0	[illegible]	0
WSW	0 *	0	0	0	[illegible]	0
W	4 *	0	1	[illegible]	0	0
WNW	47 *	0	3	22	9	11	1
NW	122 *	0	3	31	4[illegible]	29	14
NNW	37 *	0	1	17	7	9	1
TOTAL	211	0	10	75	57	56	17
PERIODS		4	7	10	13	16	19

TYPHOON WAVES POINT 8

H.1/10 = 7.1 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0 *	0	0	0	0	0	0
NNE	0 *	0	0	0	0	0	0
NE	0 *	0	0	0	0	0	0
ENE	0 *	0	0	0	0	0	0
E	0 *	0	0	0	0	0	0
ESE	0 *	0	0	0	0	0	0
SE	0 *	0	0	0	0	0	0
SSE	0 *	0	0	0	0	0	0
S	5 *	0	1	4	0	0	0
SSW	57 *	0	2	19	10	21	3
SW	182 *	0	3	26	60	58	34
WSW	76 *	0	1	19	10	38	6
W	2 *	0	0	1	0	0	0
WNW	0 *	0	0	0	0	0	0
NW	0 *	0	0	0	0	0	0
NNW	0 *	0	0	0	0	0	0
TOTAL	323	0	8	71	81	117	44
PERIODS		4	7	10	13	16	19

TYPHOON WAVES POINT 9

H.1/1 = 6.1 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0 *	0	0	0	0	0	0
NNE	0 *	0	0	0	0	0	0
NE	15 *	0	1	8	4	1	0
ENE	72 *	0	2	17	29	9	13
E	134 *	0	2	23	43	39	27
ESE	14 *	0	0	3	9	0	0
SE	0 *	0	0	0	0	0	0
SSE	0 *	0	0	0	0	0	0
S	0 *	0	0	0	0	0	0
SSW	0 *	0	0	0	0	0	0
SW	0 *	0	0	0	0	0	0
WSW	0 *	0	0	0	0	0	0
W	0 *	0	0	0	0	0	0
WNW	0 *	0	0	0	0	0	0
NW	0 *	0	0	0	0	0	0
NNW	0 *	0	0	0	0	0	0
TOTAL	237	0	7	52	46	49	42
PERIODS		4	7	10	13	16	19

TYPHOON WAVES POINT 10

H.1/1 = 6.5 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0 *	0	0	[illegible]	0	0	0
NNE	0 *	0	0	[illegible]	0	0	0
NE	0 *	0	0	[illegible]	0	0	0
ENE	0 *	0	0	[illegible]	0	0	0
E	0 *	0	0	[illegible]	0	0	0
ESE	0 *	0	0	[illegible]	0	0	0
SE	0 *	0	0	[illegible]	0	0	0
SSE	0 *	0	0	[illegible]	0	0	0
S	0 *	0	0	0	0	0	0
SSW	0 *	0	0	0	0	0	0
SW	9 *	0	1	5	1	0	0
WSW	44 *	0	2	14	21	3	3
W	158 *	0	2	30	46	40	38
WNW	54 *	0	2	11	25	8	7
NW	4 *	0	0	2	0	0	0
NNW	0 *	0	0	0	0	0	0
TOTAL	272	0	9	63	94	52	51
PERIODS		4	7	10	13	16	19

TYPHOON WAVES POINT 11

H.1/10 = 5.2 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	93 *	0	4	30	27	19	12
NNE	21 *	0	2	7	9	1	1
NE	2 *	0	1	1	0	0	0
ENE	0 *	0	0	0	0	0	0
E	0 *	0	0	0	0	0	0
ESE	0 *	0	0	0	0	0	0
SE	0 *	0	0	0	0	0	0
SSE	0 *	0	0	0	0	0	0
S	0 *	0	0	0	0	0	0
SSW	0 *	0	0	0	0	0	0
SW	0 *	0	0	0	0	0	0
WSW	0 *	0	0	0	0	0	0
W	0 *	0	0	0	0	0	0
WNW	0 *	0	0	0	0	0	0
NW	9 *	0	1	5	1	0	0
NNW	46 *	0	3	16	19	2	4
TOTAL	172	0	13	60	58	22	17
PERIODS		4	7	10	13	16	19

TYPHOON POINT 12

H.1/10 = 7.3 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0 *	0	0	0	0	0	0
NNE	0 *	0	0	0	0	0	0
NE	0 *	0	0	0	0	0	0
ENE	0 *	0	0	0	0	0	0
E	0 *	0	0	0	0	0	0
ESE	0 *	0	0	0	0	0	0
SE	20 *	0	1	8	4	2	3
SSE	77 *	0	1	16	34	9	16
S	172 *	0	1	25	50	50	43
SSW	68 *	0	0	8	22	6	29
SW	1 *	0	0	0	0	0	0
WSW	0 *	0	0	0	0	0	0
W	0 *	0	0	0	0	0	0
WNW	0 *	0	0	0	0	0	0
NW	0 *	0	0	0	0	0	0
NNW	0 *	0	0	0	0	0	0
TOTAL	340	0	6	66	112	69	92
PERIODS		4	7	10	13	16	19

0.	0.	.	0.	0.	0.	.	0.	.	0.	0.	3.	3.	3.	3.	3.	0.	0.	0.	0.	3.	3.	3.	3.	3.	3.	3.	3.	.	0.	.	0.	0.	0.	3.	3.	3.	3.	3.	3.
0.	0.	.	0.	0.	0.	.	0.	0.	3.	3.	3.	3.	3.	3.	3.	0.	0.	0.	0.	3.	3.	3.	3.	2.	1.	3.	2.	.	0.	.	0.	0.	3.	3.	3.	3.	3.	3.	3.
0.	0.	.	0.	.	0.	.	0.	3.	3.	3.	3.	3.	3.	3.	1.	0.	0.	0.	0.	3.	3.	3.	2.	.	0.	2.	0.	0.	0.	0.	0.	3.	3.	3.	3.	3.	3.	3.	3.
.	0.	.	0.	.	0.	.	2.	3.	3.	3.	3.	3.	3.	3.	0.	0.	.	3.	0.	3.	2.	1.	0.	.	0.	0.	0.	0.	0.	0.	.	3.	3.	3.	3.	3.	3.	3.	3.
.	0.	.	0.	0.	0.	.	0.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	0.	6.	6.	.	3.	0.	0.	.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
.	0.	.	0.	0.	0.	.	0.	3.	3.	3.	3.	3.	3.	3.	4.	4.	5.	5.	4.	2.	2.	2.	4.	4.	4.	3.	0.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
.	0.	.	0.	0.	0.	.	0.	0.	3.	3.	3.	3.	3.	4.	5.	6.	6.	6.	6.	.	0.	0.	6.	6.	5.	4.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
.	0.	.	0.	0.	0.	.	0.	0.	3.	3.	3.	4.	4.	5.	6.	8.	9.	9.	8.	.	.	.	9.	4.	6.	5.	4.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
.	0.	.	0.	0.	0.	.	0.	.	3.	3.	3.	4.	5.	7.	8.	10.	11.	11.	11.	.	0.	11.	11.	[illegible]	8.	6.	5.	4.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
.	0.	.	0.	0.	0.	.	.	0.	0.	3.	4.	5.	7.	8.	10.	11.	13.	13.	13.	.	0.	14.	13.	11.	10.	8.	7.	5.	4.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
0.	0.	.	0.	0.	0.	.	0.	.	0.	4.	5.	7.	9.	10.	[illegible]	12.	13.	14.	15.	15.	16.	25.	14.	12.	11.	[illegible]	8.	6.	5.	4.	3.	3.	3.	3.	3.	3.	3.	3.	3.
.	0.	.	0.	0.	0.	.	0.	.	.	5.	6.	8.	[illegible]	10.	12.	13.	14.	15.	16.	16.	17.	16.	14.	14.	12.	11.	10.	8.	6.	4.	3.	3.	3.	3.	3.	3.	3.	3.	3.
.	0.	.	0.	0.	0.	.	0.	.	0.	6.	8.	9.	10.	12.	12.	13.	14.	16.	17.	18.	17.	16.	15.	14.	14.	12.	11.	[illegible]	8.	6.	4.	3.	3.	3.	3.	4.	3.	3.	3.
0.	0.	.	0.	0.	0.	.	0.	0.	5.	7.	9.	10.	12.	12.	13.	14.	15.	16.	19.	19.	17.	17.	17.	16.	15.	14.	13.	11.	9.	7.	5.	4.	3.	3.	3.	4.	3.	3.	3.
0.	0.	.	.	.	0.	.	0.	4.	5.	7.	9.	[illegible]	11.	13.	13.	14.	14.	16.	17.	[illegible]	19.	18.	19.	[illegible]	17.	15.	14.	12.	10.	7.	5.	4.	3.	3.	3.	4.	3.	3.	3.
0.	0.	.	.	.	0.	.	0.	4.	5.	7.	9.	[illegible]	12.	13.	15.	16.	13.	12.	17.	21.	19.	[illegible]	21.	18.	17.	15.	13.	12.	[illegible]	7.	5.	4.	3.	3.	3.	4.	3.	3.	3.
0.	0.	.	0.	.	0.	.	3.	4.	5.	7.	9.	11.	12.	13.	16.	16.	11.	11.	12.	17.	24.	22.	21.	19.	17.	15.	13.	13.	[illegible]	7.	5.	4.	3.	3.	3.	4.	3.	3.	3.
0.	0.	.	0.	0.	0.	.	3.	4.	5.	7.	9.	11.	12.	13.	15.	15.	13.	12.	13.	[illegible]	25.	23.	20.	19.	17.	15.	14.	12.	[illegible]	7.	5.	4.	3.	3.	3.	4.	3.	3.	3.
0.	0.	.	0.	0.	3.	3.	2.	.	5.	7.	9.	11.	12.	17.	14.	15.	15.	15.	20.	22.	21.	19.	18.	15.	17.	15.	13.	11.	9.	7.	5.	4.	3.	3.	3.	4.	3.	3.	3.
.	0.	.	.	.	3.	2.	0.	.	5.	7.	9.	10.	11.	13.	14.	15.	16.	17.	20.	22.	20.	18.	16.	16.	15.	14.	13.	11.	9.	6.	5.	4.	3.	3.	3.	4.	3.	3.	3.
.	0.	.	3.	3.	3.	2.	0.	.	5.	6.	8.	9.	10.	12.	13.	14.	16.	17.	19.	19.	19.	17.	16.	14.	13.	13.	12.	11.	8.	6.	4.	3.	3.	3.	3.	4.	3.	3.	3.
0.	3.	3.	4.	4.	3.	2.	0.	.	4.	5.	6.	8.	9.	11.	12.	14.	14.	16.	17.	17.	17.	16.	14.	13.	12.	11.	10.	9.	7.	5.	4.	3.	3.	3.	4.	4.	3.	3.	3.
3.	3.	3.	3.	4.	3.	2.	0.	3.	3.	4.	5.	6.	9.	10.	11.	12.	14.	15.	15.	[illegible]	15.	14.	13.	13.	11.	[illegible]	8.	7.	5.	4.	3.	3.	3.	3.	4.	3.	3.	3.	3.
3.	3.	3.	3.	4.	4.	5.	3.	3.	3.	4.	4.	6.	7.	9.	[illegible]	12.	12.	13.	13.	[illegible]	13.	13.	12.	11.	10.	8.	7.	5.	4.	4.	3.	3.	3.	3.	4.	3.	3.	3.	3.
3.	3.	3.	3.	3.	4.	3.	3.	3.	3.	3.	4.	4.	6.	7.	9.	10.	11.	11.	12.	12.	12.	12.	11.	[illegible]	9.	7.	5.	4.	4.	3.	3.	3.	3.	4.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	4.	4.	3.	3.	3.	3.	3.	4.	5.	6.	7.	8.	9.	9.	10.	[illegible]	10.	10.	[illegible]	8.	7.	5.	4.	3.	3.	3.	3.	3.	4.	4.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	4.	3.	3.	3.	3.	3.	3.	4.	4.	6.	7.	7.	7.	8.	8.	8.	8.	7.	6.	5.	4.	3.	3.	3.	3.	3.	4.	4.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	4.	4.	5.	5.	5.	6.	6.	6.	6.	5.	5.	4.	3.	3.	3.	3.	3.	4.	4.	3.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	2.	.	0.	4.	.	3.	3.	3.	3.	3.	4.	4.	4.	4.	4.	4.	4.	4.	3.	3.	3.	3.	3.	3.	3.	4.	3.	3.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	.	.	0.	3.	4.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	4.	4.	3.	3.	3.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	.	0.	0.	4.	4.	4.	4.	4.	4.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	4.	4.	4.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	.	0.	0.	3.	3.	4.	4.	4.	4.	4.	4.	4.	4.	3.	3.	3.	4.	3.	4.	4.	4.	4.	4.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	.	0.	0.	3.	3.	3.	3.	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	.	.	0.	3.	3.	3.	3.	3.	3.	3.	4.	4.	4.	4.	4.	4.	4.	4.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	3.	0.	0.	2.	2.	2.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	2.	2.	.	3.	.	0.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
1.	2.	2.	2.	2.	2.	.	0.	1.	2.	2.	0.	1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.

b-1. The significant wave height (H 1/3 in feet) distribution in typhoon area. "O" indicates the land area and the distance between the grid points is 40 NM.

-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	-1.	-1.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	-1.	-1.	2.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	2.	-1.	2.	2.	2.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	-1.	2.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	3.	3.	3.	3.	-1.	-1.	3.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	3.	3.	4.	4.	4.	-1.	-1.	4.	3.	3.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	3.	3.	4.	4.	5.	5.	5.	5.	5.	4.	4.	3.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	3.	3.	4.	5.	5.	6.	6.	6.	6.	6.	5.	5.	4.	3.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	3.	3.	4.	5.	5.	6.	7.	7.	7.	7.	7.	6.	5.	5.	4.	3.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	3.	4.	4.	5.	6.	7.	8.	9.	4.	9.	8.	7.	6.	5.	4.	4.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	3.	3.	4.	5.	6.	7.	8.	10.	11.	11.	10.	9.	8.	7.	6.	5.	4.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	3.	3.	4.	5.	6.	8.	9.	12.	14.	15.	13.	10.	9.	7.	6.	5.	4.	3.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	3.	3.	4.	5.	7.	8.	10.	13.	16.	16.	14.	11.	9.	7.	6.	5.	4.	3.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	3.	3.	4.	5.	6.	8.	10.	13.	16.	16.	14.	11.	9.	7.	6.	5.	4.	3.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	2.	2.	2.	-1.	2.	2.	3.	3.	4.	5.	6.	7.	9.	11.	13.	13.	12.	10.	8.	7.	6.	5.	4.	3.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	-1.	-1.	2.	2.	-1.	-1.	2.	2.	2.	3.	4.	5.	6.	7.	8.	9.	11.	11.	10.	9.	7.	6.	5.	5.	4.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	-1.	-1.	2.	2.	2.	2.	-1.	-1.	2.	2.	2.	3.	4.	4.	5.	6.	7.	8.	8.	4.	8.	7.	7.	6.	5.	4.	3.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
-1.	2.	2.	2.	2.	2.	2.	-1.	-1.	2.	2.	2.	3.	3.	4.	4.	5.	6.	6.	7.	7.	7.	6.	6.	5.	4.	4.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	-1.	2.	2.	2.	2.	2.	3.	3.	4.	4.	5.	5.	6.	6.	5.	5.	5.	4.	4.	3.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	3.	3.	4.	4.	4.	5.	5.	4.	4.	4.	4.	3.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	3.	3.	3.	4.	4.	4.	4.	3.	3.	3.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	3.	3.	3.	3.	3.	3.	3.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	-1.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	-1.	2.	-1.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	-1.	-1.	2.	2.	2.	-1.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.

b-2. The maximum wave period distribution in typhoon area. "-1" indicates the land area.

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-1.-1.-1.-1.-1.-1.-1.-1.-1.-1.-1.12.12.12.12.-1.-1.-1.12.12.12.12.12.12.12.12.12.12.12.12.12.12.-1.-1.12.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.-1.-1.12.12.12.12.-1.-1.-1.-1.-1.12.12.12.12.12.12.12.12.12.12.12.12.12.-1.-1.-1.12.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.-1.-1.-1.12.12.12.12.12.-1.-1.-1.12.12.12.12.12.12.12.12.12.12.12.12.-1.-1.-1.12.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.-1.-1.-1.12.12.12.12.12.-1.-1.-1.-1.12.12.12.12.12.12.12.-1.-1.-1.-1.-1.-1.12.12.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.-1.12.12.12.12.12.14.14.-1.-1.-1.-1.13.13.13.13.13.12.12.12.-1.-1.-1.-1.-1.12.12.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.12.12.12.12.15.14.14.14.-1.-1.-1.-1.13.13.13.13.-1.-1.12.-1.-1.-1.-1.-1.12.12.12.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.12.12.12.12.15.15.14.14.-1.-1.-1.14.-1.13.13.13.-1.-1.-1.-1.-1.-1.-1.-1.-1.12.12.12.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.12.15.15.15.15.16.14.14.14.14.14.13.13.-1.-1.-1.-1.12.-1.-1.-1.12.11.12.12.12.12.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.15.15.15.15.15.15.14.14.14.14.14.13.13.13.13.13.12.12.12.-1.12.12.11.11.12.12.12.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.-1.15.15.15.15.15.15.14.14.14.14.13.-1.-1.-1.12.12.12.12.12.12.11.11.11.11.12.12.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.-1.15.15.15.15.15.15.14.14.14.13.-1.-1.-1.12.12.12.12.12.11.11.11.11.11.12.12.12.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.-1.16.16.15.15.15.15.15.14.14.14.13.-1.-1.13.12.12.12.12.11.11.11.11.11.11.12.12.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.-1.16.16.15.15.15.15.15.14.14.13.-1.-1.13.12.12.12.11.11.11.11.11.11.11.11.11.11.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.-1.16.16.16.15.15.15.15.14.14.14.13.13.12.12.12.12.11.11.11.11.11.11.11.11.11.12.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.-1.16.16.16.16.15.15.15.15.14.14.13.13.12.12.12.11.11.11.11.11.11.11.10.10.10.10.12.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.-1.-1.16.16.16.16.16.15.15.15.14.14.13.13.12.12.11.11.11.11.11.10.10.10.10.10.10.10.10.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1.-1. 1. 1. 1.16.16.16.16.16.15.15.14.13.12.12.11.11.11.11.10.10.10.10.10.10.10.10.10.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1. 1. 1. 1. 1. 1. 1.16.16.15.16.15.14.13.12.11.11.11.10.10.10.10.10.10.10.10.10.10.10.12.12.12.12.
-1.-1.-1.-1.-1.-1.-1.-1. 1. 1. 1. 1. 1. 1. 1. 1. 1.16.16.14.12.11.11.10.10.10.10.10.10.10.10.10.10.10.10.10.12.12.12.12.
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-1.-1.-1.-1.-1. 2. 2.-1.-1. 2. 2. 2. 2. 2. 3. 3. 3. 4. 4. 5. 6. 7. 7. 8. 8. 8. 9. 9. 9. 9. 9. 9. 9. 9. 9. 9.12.12.12.12.
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12.12.12.12.12. 3. 3. 3. 3. 3. 3. 3. 4. 4. 4. 4. 4. 5. 5. 5. 6. 6. 7. 7. 7. 7. 8. 8. 8. 8. 8. 8. 8. 8. 8.12.12.12.12.12.
12.12.12.12.12.12. 3. 3. 3. 3. 3. 4. 4. 4. 4. 4. 5. 5. 5. 6. 6. 6. 6. 7. 7. 7. 7. 8. 8. 8. 8. 8. 8. 8.12.12.12.12.12.12.
12.12.12.12.12.12. 3. 3. 3. 3. 4. 4. 4. 4. 4. 5. 5. 5. 5. 6. 6. 6. 6. 7. 7. 7. 7. 7. 8. 8. 8. 8. 8. 8.12.12.12.12.12.12.
12.12.12.12.12.12.12. 3. 4. 4. 4. 4. 4. 4. 4. 5. 5. 5. 5. 6. 6. 6. 6. 7. 7. 7. 7. 7. 7. 8. 8. 8. 8.12.12.12.12.12.12.12.
12.12.12.12.12.12.12.12. 4. 4. 4. 4. 4. 4. 5. 5. 5. 5. 5. 6. 6. 6. 6. 7. 7. 7. 7. 7. 7. 7. 8. 8.12.12.12.12.12.12.12.12.
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12.12.12.12.12.12.-1.-1.-1.12. 4. 4. 4. 5. 5. 5. 5. 5. 5. 6. 6. 6. 6. 6. 7. 7. 7. 7. 7. 7.12.12.12.12.12.12.12.12.12.12.
12.12.12.12.12.12.-1.-1.-1.-1.12. 4. 5. 5. 5. 5. 5. 5. 5. 6. 6. 6. 6. 6. 7. 7. 7. 7. 7.12.12.12.12.12.12.12.12.12.12.12.
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12.12.12.12.12.12.-1.-1.-1.12.12.12.12.12.12.12. 5. 5. 6. 6. 6. 6. 6. 6.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.
12.12.12.12.12.12.-1.-1.-1.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.
12.12.12.12.12.12.12.-1.-1.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.
12.12.12.12.12.12.12.12.-1.12.-1.-1.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.
12.12.12.12.12.12.-1.-1.12.12.12.-1.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.12.
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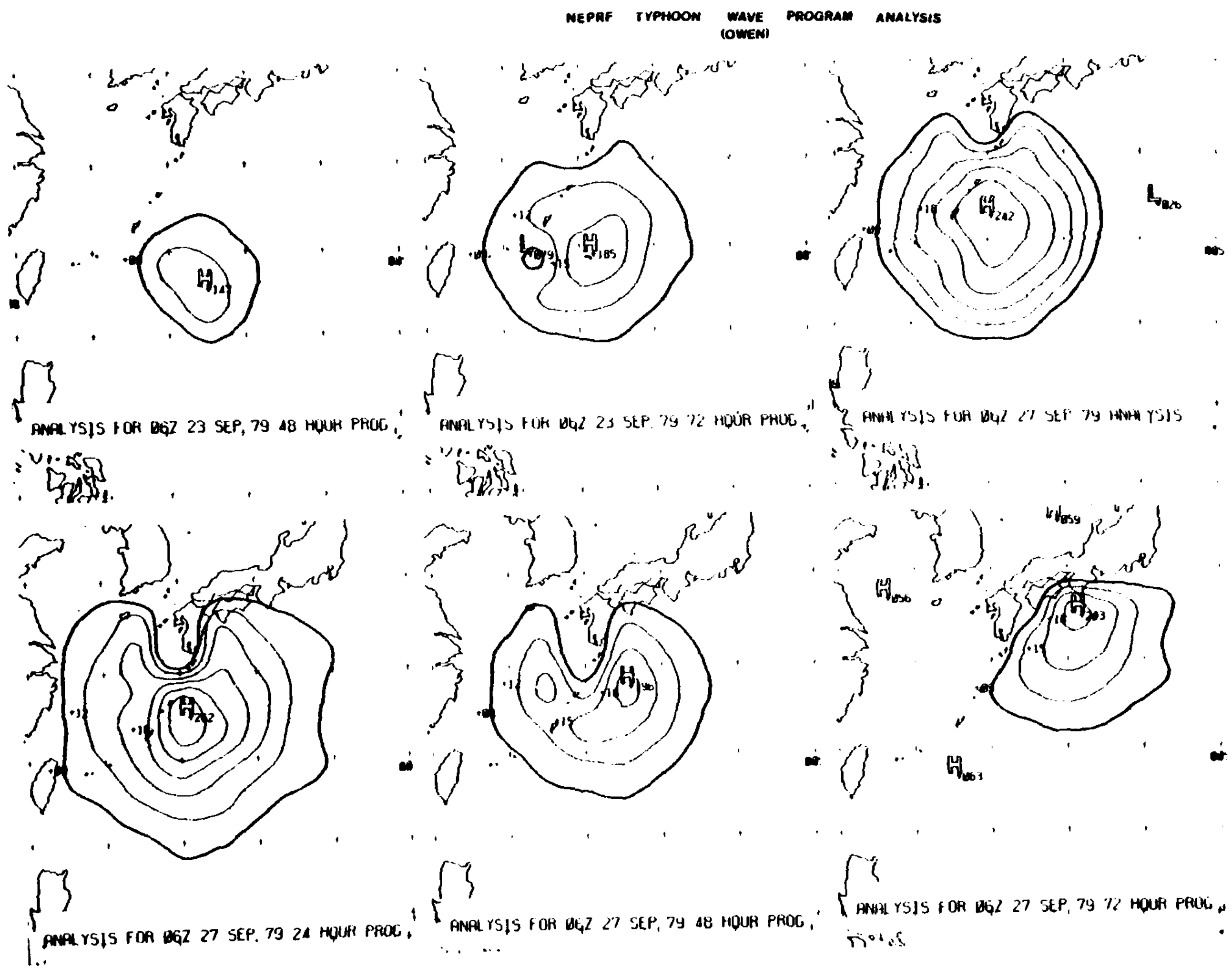
b-3. The maximum wind wave directions distribution. The direction indicates with 16 unit point rose, from North (1) to NNE (16) with CCW direction.

c. NEPRF Typhoon Wave Program Analysis for Typhoon Owen during the typhoon period from the time of the first typhoon warning to 72 hours later, based on post-analysis data.



ANALYSIS FOR ØGZ 27 SEP. 79 12 HOUR PROG.

APPENDIX B

Sea Spectra at Source Region for Three Typhoons and Significant Wave Distribution

The following tables and figures show the period-direction spectrum at selected source grid point and NEPRF typhoon wave program analysis for wave height (H 1/3 in feet) distribution around the typhoon center, respectively.

a-1. NEPRF Typhoon Wave Model (period-direction spectrum at each selected grid point) for Typhoon Hope.

a-2. NEPRF Typhoon Wave Program Analysis for Typhoon Hope.

b-1. NEPRF Typhoon Wave Model (period-direction spectrum at each selected source grid point) for Typhoon Irving.

b-2. NEPRF Typhoon Wave Program Analysis for Typhoon Irving.

c-1. NEPRF Typhoon Wave Model (period-direction spectrum at each selected source grid point) for Typhoon Owen.

c-2. NEPRF Typhoon Wave Program Analysis for Typhoon Owen.

a-1. NEPRF Typhoon Wave Model
(Hope)

NEPRF TYPHOON WAVE MODEL
(HOPE)

TYPHOON WAVES POINT 4

1979 07 30 12 H.1/10= 6.2 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	*	0	0	0	0	0	0
NNE	0	*	0	0	0	0	0	0
NE	0	*	0	0	0	0	0	0
ENE	4	*	0	0	0	4	0	0
E	13	*	0	0	12	0	0	0
ESE	55	*	0	9	30	15	0	0
SE	105	*	0	3	39	46	0	15
SSE	63	*	0	7	19	11	9	14
S	0	*	0	0	0	0	0	0
SSW	2	*	0	0	0	2	0	0
SW	0	*	0	0	0	0	0	0
WSW	0	*	0	0	0	0	0	0
W	0	*	0	0	0	0	0	0
WNW	0	*	0	0	0	0	0	0
NW	0	*	0	0	0	0	0	0
NNW	0	*	0	0	0	0	0	0
TOTAL	245		0	21	1[illegible]3	8[illegible]	9	30
	PERIODS		4	7	10	13	16	19

TYPHOON POINT 12

07 30 12 H.1/10= 7.0 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	*	0	0	0	0	0	0
NNE	0	*	0	0	0	0	0	0
NE	0	*	0	0	0	0	0	0
ENE	0	*	0	0	0	0	0	0
E	0	*	0	0	0	0	0	0
ESE	13	*	0	2	6	3	0	0
SE	103	*	0	6	30	35	16	14
SSE	147	*	0	8	28	31	36	42
S	38	*	0	1	11	10	8	7
SSW	3	*	0	0	0	3	0	0
SW	0	*	0	0	0	0	0	0
WSW	0	*	0	0	0	0	0	0
W	0	*	0	0	0	0	0	0
WNW	0	*	0	0	0	0	0	0
NW	0	*	0	0	0	0	0	0
NNW	0	*	0	0	0	0	0	0
TOTAL	306		0	18	77	84	60	64
	PERIODS		4	7	10	13	16	19

TYPHOON. WAVES POINT 4

07 31 00 H.1/10= 5.8 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	*	0	0	0	0	0	0
NNE	0	*	0	0	0	0	0	0
NE	0	*	0	0	0	0	0	0
ENE	0	*	0	0	0	0	0	0
E	1	*	0	1	0	0	0	0
ESE	6	*	0	4	0	2	0	0
SE	101	*	0	7	43	27	6	16
SSE	69	*	0	4	15	2[illegible]	13	15
S	35	*	0	1	9	3	16	4
SSW	0	*	0	0	0	0	0	0
SW	0	*	0	0	0	0	0	0
WSW	0	*	0	0	0	0	0	0
W	0	*	0	0	0	0	0	0
WNW	0	*	0	0	0	0	0	0
NW	0	*	0	0	0	0	0	0
NNW	0	*	0	0	0	0	0	0
TOTAL	214		0	19	69	55	35	35
	PERIODS		4	7	10	13	16	19

TYPHOON POINT 12

07 31 00 H.1/10= 6.5 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	*	0	0	0	0	0	0
NNE	0	*	0	0	0	0	0	0
NE	0	*	0	0	0	0	0	0
ENE	0	*	0	0	0	0	0	0
E	0	*	0	0	0	0	0	0
ESE	2	*	0	1	0	1	0	0
SE	72	*	0	3	27	23	8	8
SSE	123	*	0	3	37	43	19	19
S	67	*	0	2	17	19	16	11
SSW	0	*	0	0	0	0	0	0
SW	0	*	0	0	0	0	0	0
WSW	0	*	0	0	0	0	0	0
W	0	*	0	0	0	0	0	0
WNW	0	*	0	0	0	0	0	0
NW	0	*	0	0	0	0	0	0
NNW	0	*	0	0	0	0	0	0
TOTAL	266		0	10	82	89	44	39
	PERIODS		4	7	10	13	16	19

TYPHOON WAVES POINT 4

07 31 12 H.1/10= 4.5 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	*	0	0	0	0	0	0
NNE	0	*	0	0	0	0	0	0
NE	0	*	0	0	0	0	0	0
ENE	0	*	0	0	0	0	0	0
E	3	*	0	0	0	0	0	3
ESE	9	*	0	1	0	8	0	0
SE	160	*	0	3	53	56	9	37
SSE	65	*	0	1	0	14	0	50
S	121	*	0	0	23	30	46	20
SSW	44	*	0	0	0	3	0	40
SW	49	*	0	0	11	18	3	14
WSW	0	*	0	0	0	0	0	0
W	0	*	0	0	0	0	0	0
WNW	0	*	0	0	0	0	0	0
NW	0	*	0	0	0	0	0	0
NNW	0	*	0	0	0	0	0	0
TOTAL	457		0	9	97	132	59	167
	PERIODS		4	7	10	13	16	19

TYPHOON WAVES POINT [illegible]

08 01 00 H.1/1[illegible]= 12.3 [illegible]

NORTH CORRESPONDS TO THE AZIMUTH [illegible]

N	[illegible]	*	0	0	[illegible]	0	[illegible]	1
NNE	2	*	0	[illegible]	[illegible]	2	[illegible]	0
NE	40	*	0	0	[illegible]	1[illegible]	18	9
ENE	37	*	0	0	4	9	3	19
E	42	*	0	0	11	11	14	3
ESE	97	*	[illegible]	[illegible]	17	21	18	[illegible]9
SE	161	*	0	0	31	36	50	42
SSE	167	*	5	6	31	41	33	53
S	13[illegible]	*	0	4	37	39	41	13
SSW	114	*	[illegible]	5	23	30	19	40
SW	96	*	0	0	13	25	35	22
WSW	41	*	0	0	9	10	3	18
W	14	*	0	[illegible]	5	4	4	1
WNW	1	*	[illegible]	0	[illegible]	0	[illegible]	[illegible]
NW	[illegible]	*	0	[illegible]	[illegible]	0	[illegible]	0
NNW	[illegible]	*	0	0	[illegible]	0	0	0
TOTAL	956		[illegible]	16	18[illegible]	243	243	265
	PERIODS		4	7	1[illegible]	13	16	19

TYPHOON POINT 12

08 01 00 H.1/3 = 12.4 M

NORTH CORRESPONDS TO THE AZIMUTH 36

N	[illegible] •		[illegible]	[illegible]	[illegible]	0	0
NNE	[illegible] •		[illegible]	[illegible]	[illegible]		0
NE	[illegible] •		[illegible]	[illegible]	[illegible]	[illegible]	0
ENE	[illegible] •	0	0	0	[illegible]	[illegible]	0
E	[illegible] •		[illegible]	[illegible]	[illegible]	[illegible]	0
ESE	22 •		[illegible]	6	1	14	0
SE	14[illegible] •		[illegible]	15	37	44	79
SSE	2[illegible]2 •		[illegible]	21	62	44	69
S	243 •			20	71	34	52
SSW	192 •	[illegible]	[illegible]	15	56	51	69
SW	143 •		[illegible]	16	29	61	4[illegible]
WSW	23 •		[illegible]	3	3	15	0
W	9 •		[illegible]	[illegible]	3	4	1
WNW	[illegible] •	[illegible]	[illegible]		[illegible]	[illegible]	0
NW	[illegible] •	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0
NNW	[illegible] •	0	0	0	0	0	0
TOTAL	976		[illegible]	[illegible]	265	342	274
PERIODS		4	7	10	13	16	19

TYPHOON WAVES POINT [illegible]

08 01 12 H.1/1 = 11. M

NORTH CORRESPONDS TO THE AZIMUTH 36

N	[illegible] •	0	[illegible]		0	0	0
NNE	5 •	0	0		5	0	0
NE	52 •	0	[illegible]	1[illegible]	14	19	7
ENE	23 •	0	[illegible]	3	17	0	2
E	54 •	0	1	17	7	23	5
ESE	62 •	0	1	1[illegible]	30	11	8
SE	157 •	0	1	31	43	51	30
SSE	88 •	0	3	2	38	11	15
S	131 •	0	1	26	26	47	29
SSW	58 •	0	0	11	33	3	10
SW	77 •	0	[illegible]	18	18	19	19
WSW	22 •	0	[illegible]	5	13	[illegible]	3
W	31 •	0	0	3	2	20	4
WNW	4 •	0	0	0	4	0	0
NW	1 •	0	0		0	0	1
NNW	0 •	0	0	[illegible]	0	0	0
TOTAL	769	0	9	15[illegible]	254	207	138
PERIODS		4	7	1[illegible]	13	16	19

TYPHOON WAVES POINT [illegible]

08 01 12 H.1/10 = 1[illegible].2 M

NORTH CORRESPONDS TO THE AZIMUTH 36[illegible]

N	0 •	0	0	0	0	0	0
NNE	0 •	0	0	0	0	0	0
NE	0 •	0	0	0	0	0	0
ENE	0 •	0	0	0	0	0	0
E	0 •	0	0	0	0	0	0
ESE	0 •	0	0	0	0	0	0
SE	1 •	0	0	0	0	0	1
SSE	0 •	0	0	0	0	0	0
S	11 •	0	0	5	3	2	0
SSW	98 •	0	1	22	51	8	13
SW	198 •	0	0	23	62	71	4[illegible]
WSW	186 •	0	1	29	58	55	40
W	1[illegible]6 •	0	0	18	38	18	31
WNW	5[illegible] •	0	0	8	11	18	12
NW	7 •	0	0	2	[illegible]	0	5
NNW	0 •	0	0	0	0	0	0
TOTAL	661	0	3	110	227	174	145
PERIODS		4	7	10	13	16	19

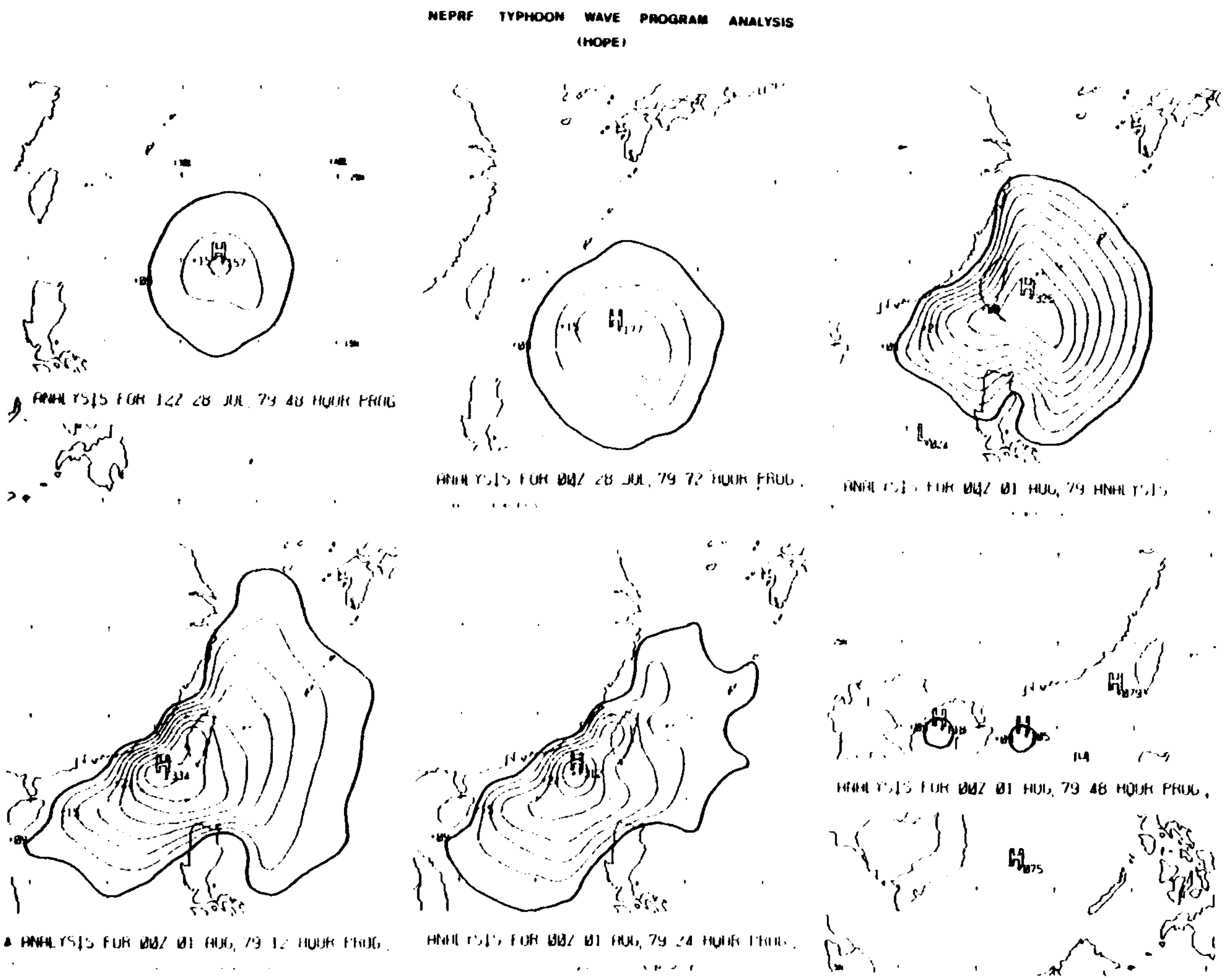
TYPHOON POINT 12

08 01 12 H.1/3 = 11.1 M

NORTH CORRESPONDS TO THE AZIMUTH 36

N	0 •	0	0	0	0	0	0
NNE	0 •	0	0	0	0	0	0
NE	1 •	0	0	0	0	0	1
ENE	0 •	0	0	0	0	0	0
E	5 •	0	0	3	1	[illegible]	[illegible]
ESE	49 •	0	0	14	26	[illegible]	7
SE	166 •	0	0	16	43	75	31
SSE	185 •	0	1	26	54	59	43
S	227 •	0	0	20	61	78	67
SSW	1[illegible]4 •	0	0	6	17	49	31
SW	26 •	0	0	4	9	0	12
WSW	15 •	0	0	1	7	5	2
W	0 •	0	0	0	0	0	0
WNW	0 •	0	0	0	0	0	0
NW	0 •	0	0	0	0	0	0
NNW	0 •	0	0	0	0	0	0
TOTAL	782	0	2	92	223	266	196
PERIODS		4	7	10	13	16	19

a-2. NEPRF Typnoon Wave Program Analysis (Hope)



b-1. NEPRF Typhoon Wave Model (Irving)

NEPRF TYPHOON WAVE MODEL (IRVING)

1979 08 13 00 — TYPHOON — POINT 12 — H.1/10 = 5.9 M

NORTH CORRESPONDS TO THE AZIMUTH 36[illegible]

N	[illegible]	[illegible]	0	0	1		0
NNE	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	0
NE	1	[illegible]	[illegible]	[illegible]	[illegible]	1	0
ENE	0	[illegible]	0	0	9	[illegible]	0
E	[illegible]	[illegible]	0	0	0	[illegible]	0
ESE	4	[illegible]	1	2	1	[illegible]	0
SE	25		4	12	6	1	[illegible]
SSE	1[illegible]	1	5	25	39	23	11
S	83	[illegible]	3	22	26	15	15
SSW	7		1	1	3	1	[illegible]
SW	[illegible]	[illegible]	[illegible]	[illegible]	1		0
WSW	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	0
W			[illegible]	[illegible]	[illegible]		0
WNW		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
NW	[illegible]		[illegible]	[illegible]	1		0
NNW			[illegible]	[illegible]	[illegible]	1	[illegible]
TOTAL	222		16	64	76	34	27
PERIODS		4	7	1[illegible]	13	16	19

08 13 00 — TYPHOON WAVES — POINT 4 — H.1/1 = 6.8 M

NORTH CORRESPONDS TO THE AZIMUTH 36

N	0	0	0	[illegible]	0	[illegible]	0
NNE	0	0	0		0	0	0
NE	0	0	0	[illegible]	0	0	0
ENE	0	[illegible]	[illegible]	[illegible]	0	0	0
E	0	0	[illegible]		0	[illegible]	0
ESE	0	0	0		0	[illegible]	[illegible]
SE	55	0	3	14	13	9	9
SSE	137	0	3	33	46	21	27
S	93	[illegible]	2	22	29	27	1[illegible]
SSW	5	0	0	1	3		[illegible]
SW	0	0	0	[illegible]	0	0	0
WSW	[illegible]	[illegible]	0		0	[illegible]	0
W	[illegible]	[illegible]			0	[illegible]	[illegible]
WNW	[illegible]	[illegible]	[illegible]		0	[illegible]	0
NW	0	0	[illegible]	[illegible]	0	[illegible]	[illegible]
NNW	[illegible]	[illegible]	[illegible]		0	[illegible]	0
TOTAL	292	[illegible]	9	81	93	69	47
PERIODS		4	7	1	13	16	19

08 13 12 — TYPHOON WAVES — POINT [illegible] — H.1/1 = [illegible]

NORTH CORRESPONDS TO THE AZIMUTH 3[illegible]

N	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
NNE	[illegible]	0	0		0	[illegible]	[illegible]
NE	[illegible]	0	[illegible]		[illegible]	[illegible]	[illegible]
ENE	1	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
E	[illegible]	0	[illegible]		[illegible]	[illegible]	0
ESE	16	0	1	5	7		[illegible]
SE	58	[illegible]	2	19	13	18	5
SSE	1[illegible]5	0	4	3	31	25	[illegible]
S	67	[illegible]	2	23	20	14	[illegible]
SSW	2	[illegible]	0	1	1		[illegible]
SW	[illegible]	[illegible]	[illegible]		[illegible]		
WSW	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
W	[illegible]	0	0		[illegible]		[illegible]
WNW	[illegible]		0		[illegible]	[illegible]	[illegible]
NW	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
NNW	[illegible]		[illegible]		[illegible]		[illegible]
TOTAL	2[illegible]3		1[illegible]	[illegible]	7[illegible]	[illegible]	[illegible]
PERIODS		4	7	1	13	16	19

08 13 12 — TYPHOON — POINT 12 — H.1/1[illegible] = 5.4 M

NORTH CORRESPONDS TO THE AZIMUTH 36

N			[illegible]		[illegible]	[illegible]	[illegible]
NNE			[illegible]		[illegible]		0
NE			[illegible]		[illegible]		[illegible]
ENE					[illegible]	[illegible]	[illegible]
E				[illegible]	[illegible]	[illegible]	[illegible]
ESE	[illegible]		[illegible]	2	1		[illegible]
SE	[illegible]		2	9	6	[illegible]	1
SSE	67		3	[illegible]	[illegible]	1[illegible]	4
S	[illegible]	[illegible]	2	[illegible]	[illegible]	21	1[illegible]
SSW	1	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]
SW				[illegible]	[illegible]	[illegible]	0
WSW							[illegible]
W							[illegible]
WNW	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]
NW	[illegible]		[illegible]			[illegible]	[illegible]
NNW			[illegible]				[illegible]
TOTAL	1[illegible]		9	[illegible]7	[illegible]	[illegible]1	[illegible]7
PERIODS		[illegible]	7	[illegible]	[illegible]	15	[illegible]

08 14 00 — TYPHOON WAVES — POINT 4 — H.1/1 = 7.[illegible] M

NORTH CORRESPONDS TO THE AZIMUTH 3[illegible]

N	0	[illegible]	[illegible]		0	[illegible]	[illegible]
NNE	1	0	0		[illegible]	[illegible]	[illegible]
NE	0	[illegible]	[illegible]		[illegible]		[illegible]
ENE	0	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
E	0	0	0	[illegible]	[illegible]	[illegible]	0
ESE	3		[illegible]		2	[illegible]	[illegible]
SE	78	[illegible]	4	1[illegible]	21	22	1[illegible]
SSE	125	[illegible]	1[illegible]	4[illegible]	[illegible]7	19	22
S	79	0	4	17	22	18	17
SSW	19		[illegible]	[illegible]	6		[illegible]
SW	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]
WSW		[illegible]			[illegible]		[illegible]
W	0	[illegible]			[illegible]		[illegible]
WNW	[illegible]	[illegible]	[illegible]				[illegible]
NW	0	[illegible]					[illegible]
NNW	[illegible]	[illegible]			[illegible]		
TOTAL	[illegible]6	[illegible]	14	[illegible]	[illegible]1	[illegible]	[illegible]
PERIODS		4	7	1	1[illegible]	16	19

08 14 00 — TYPHOON — POINT 1[illegible] — H.1/1 = [illegible]

NORTH CORRESPONDS TO THE AZIMUTH [illegible]

N							
NNE				[illegible]			
NE	[illegible]		[illegible]				[illegible]
ENE	[illegible]						
E			[illegible]				[illegible]
ESE		[illegible]		[illegible]	[illegible]		[illegible]
SE	[illegible]		2	[illegible]3	[illegible]	[illegible]	5
SSE	[illegible]		[illegible]	[illegible]	[illegible]	24	[illegible]
S	7[illegible]		[illegible]	[illegible]	[illegible]	1[illegible]	[illegible]
SSW	13		1	2	6	[illegible]	[illegible]
SW				[illegible]			[illegible]
WSW		[illegible]					
W			[illegible]				[illegible]
WNW				[illegible]	[illegible]	[illegible]	
NW			[illegible]		[illegible]		[illegible]
NNW							
TOTAL	[illegible]		12	71	[illegible]	[illegible]	[illegible]
PERIODS		[illegible]	7	[illegible]	1[illegible]	1[illegible]	[illegible]

TYPHOON WAVES POINT 4

081412 H.1/3 = 7. M

NORTH CORRESPONDS TO THE AZIMUTH 36

N	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0
ENE	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0
ESE	4	0	0	3	0	1	0
SE	76	2	2	16	16	27	13
SSE	149	0	1	[illegible]	39	32	35
S	74	0	1	19	31	13	8
SSW	4	0	0	4	0	0	0
SW	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0
TOTAL	319	[illegible]	5	82	88	74	58
PERIODS		4	7	10	13	16	19

TYPHOON POINT 1

081412 H.1/3 = 5.4 M

NORTH CORRESPONDS TO THE AZIMUTH 36

N	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0
ENE	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0
ESE	1	0	0	1	0	0	0
SE	31	0	1	4	9	5	[illegible]
SSE	125	0	1	28	[illegible]	[illegible]	27
S	94	0	1	19	29	26	18
SSW	6	0	0	4	0	0	[illegible]
SW	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0
TOTAL	259	0	5	62	73	[illegible]	42
PERIODS		4	7	10	13	16	19

TYPHOON WAVES POINT 4

081500 H.1/3 = 7.5 M

NORTH CORRESPONDS TO THE AZIMUTH 36

N	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0
ENE	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0
ESE	9	0	2	0	7	0	0
SE	31	0	4	6	10	1	7
SSE	146	0	5	46	33	23	36
S	132	0	9	[illegible]	36	23	22
SSW	33	0	2	[illegible]	0	5	14
SW	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0
TOTAL	354	1	23	[illegible]	88	56	41
PERIODS		4	7	10	13	16	19

TYPHOON POINT 12

081500 H.1/3 = 6.8 M

NORTH CORRESPONDS TO THE AZIMUTH 36

N	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0
ENE	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0
ESE	2	0	1	0	1	0	0
SE	24	0	2	5	9	3	3
SSE	[illegible]	0	3	29	20	17	40
S	125	0	3	34	41	33	12
SSW	[illegible]	0	1	7	2	3	14
SW	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0
TOTAL	293	0	12	77	75	57	70
PERIODS		4	7	10	13	16	19

TYPHOON WAVES POINT 4

081512 H.1/3 = [illegible] M

NORTH CORRESPONDS TO THE AZIMUTH 36

N	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0
NE	1	0	0	0	0	0	1
ENE	35	0	0	19	15	0	0
E	74	0	1	16	35	11	[illegible]
ESE	131	0	3	25	27	33	41
SE	169	0	1	[illegible]	64	28	33
SSE	157	0	2	21	40	41	52
S	73	0	0	13	13	24	15
SSW	21	0	0	0	21	0	0
SW	3	0	0	0	0	0	3
WSW	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0
TOTAL	669	0	9	142	220	138	158
PERIODS		4	7	10	13	16	19

TYPHOON POINT 12

081512 H.1/3 = 8.9 M

NORTH CORRESPONDS TO THE AZIMUTH 36

N	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0
ENE	1	0	0	0	1	0	0
E	0	0	0	0	0	0	0
ESE	[illegible]	0	0	5	4	0	0
SE	[illegible]	0	0	17	33	32	22
SSE	212	0	1	21	56	55	75
S	153	0	0	17	[illegible]	53	43
SSW	17	0	0	0	16	0	0
SW	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0
TOTAL	[illegible]	0	3	63	[illegible]	143	142
PERIODS		4	7	10	13	16	19

(IRVING)

TYPHOON WAVES POINT 8

081512 H.1/10= 9.8 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	*	0	0	0	0	0	0
NNE	0	*	0	0	0	0	0	0
NE	0	*	0	0	0	0	0	0
ENE	0	*	0	0	0	0	0	0
E	0	*	0	0	0	0	0	0
ESE	0	*	0	0	0	0	0	0
SE	3	*	0	0	0	0	0	3
SSE	13	*	0	0	0	13	0	0
S	62	*	0	1	17	15	14	13
SSW	164	*	0	3	29	33	46	52
SW	197	*	0	1	50	75	32	38
WSW	101	*	0	3	6	16	34	40
W	52	*	0	0	10	0	21	20
WNW	3	*	0	0	0	3	0	0
NW	1	*	0	0	0	0	0	1
NNW	0	*	0	0	0	0	0	0
TOTAL	600		0	9	114	158	148	169
	PERIODS		4	7	10	13	16	19

TYPHOON WAVES POINT 4

081600 H.1/10= 7.9 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	*	0	0	0	0	0	0
NNE	0	*	0	0	0	0	0	0
NE	0	*	0	0	0	0	0	0
ENE	0	*	0	0	0	0	0	0
E	0	*	0	0	0	0	0	0
ESE	25	*	0	1	3	10	10	0
SE	135	*	0	1	25	49	30	29
SSE	164	*	0	1	33	62	50	16
S	65	*	0	0	15	14	19	15
SSW	0	*	0	0	0	0	0	0
SW	0	*	0	0	0	0	0	0
WSW	0	*	0	0	0	0	0	0
W	0	*	0	0	0	0	0	0
WNW	0	*	0	0	0	0	0	0
NW	0	*	0	0	0	0	0	0
NNW	0	*	0	0	0	0	0	0
TOTAL	390		0	4	79	136	110	61
	PERIODS		4	7	10	13	16	19

TYPHOON WAVES POINT 8

081600 H.1/10= 8.0 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	*	0	0	0	0	0	0
NNE	0	*	0	0	0	0	0	0
NE	0	*	0	0	0	0	0	0
ENE	0	*	0	0	0	0	0	0
E	0	*	0	0	0	0	0	0
ESE	0	*	0	0	0	0	0	0
SE	0	*	0	0	0	0	0	0
SSE	0	*	0	0	0	0	0	0
S	90	*	0	0	16	20	31	21
SSW	175	*	0	0	33	62	47	31
SW	119	*	0	1	15	43	32	26
WSW	16	*	0	0	2	8	5	0
W	0	*	0	0	0	0	0	0
WNW	0	*	0	0	0	0	0	0
NW	0	*	0	0	0	0	0	0
NNW	0	*	0	0	0	0	0	0
TOTAL	402		0	3	67	135	117	78
	PERIODS		4	7	10	13	16	19

TYPHOON POINT 12

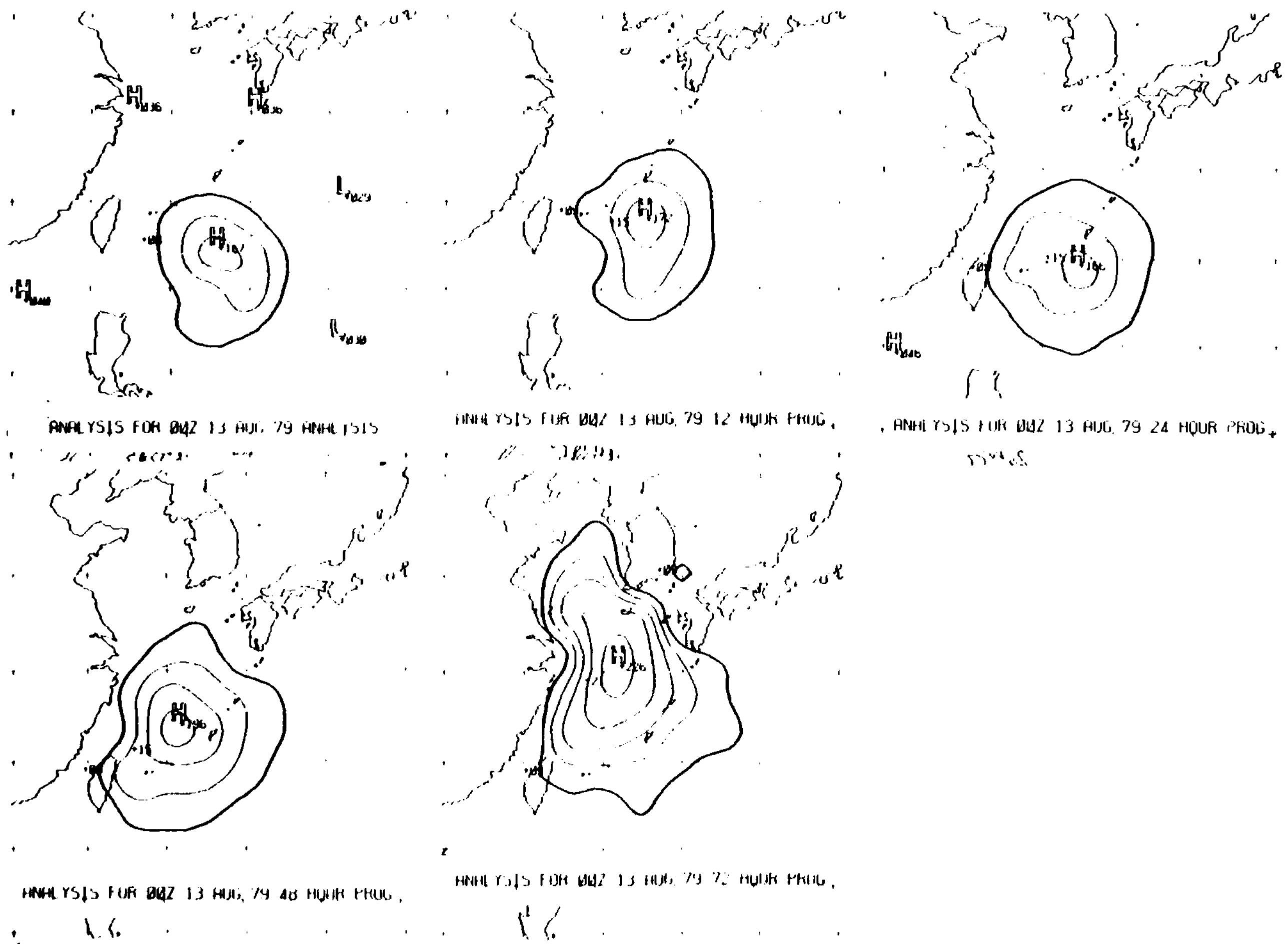
081600 H.1/10= 7.7 M

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	*	0	0	0	0	0	0
NNE	0	*	0	0	0	0	0	0
NE	0	*	0	0	0	0	0	0
ENE	0	*	0	0	0	0	0	0
E	0	*	0	0	0	0	0	0
ESE	2	*	0	0	0	1	0	0
SE	72	*	0	1	16	21	20	12
SSE	179	*	0	1	24	54	60	38
S	122	*	0	1	21	40	40	19
SSW	2	*	0	0	0	0	0	1
SW	0	*	0	0	0	0	0	0
WSW	0	*	0	0	0	0	0	0
W	0	*	0	0	0	0	0	0
WNW	0	*	0	0	0	0	0	0
NW	0	*	0	0	0	0	0	0
NNW	0	*	0	0	0	0	0	0
TOTAL	379		0	5	63	117	121	72
	PERIODS		4	7	10	13	16	19

b-2. NEPRF Typhoon Wave Program Analysis (Irvinq)

NEPRF TYPHOON WAVE PROGRAM ANALYSIS
(IRVING)



c-1. NEPRF Typhoon Wave Model (Owen)

NEPRF TYPHOON WAVE MODEL

(OWEN)

TYPHOON WAVES POINT [illegible]

1979 09 25 06 H 1/3 = [illegible]

NORTH CORRESPONDS TO THE AZIMUTH [illegible]

N							
NNE							
NE							
ENE	[illegible]						[illegible]
E	1						
ESE	32		6	6	17	1	
SE	33		8	25	27	26	8
SSE	74		7	25	31	8	9
S	31		4	1	1	4	2
SSW							
SW							
WSW							
W							
WNW							
NW							
NNW							
TOTAL	252	[illegible]	25	63	[illegible]	[illegible]	[illegible]
PERIOD		4	7	10	13	16	19

TYPHOON [illegible] POINT 12

09 25 06 H 1/3 = 5.4 M

NORTH CORRESPONDS TO THE AZIMUTH 36

N		[illegible]		[illegible]		
NNE						
NE						
ENE						
E						
ESE	11	2	4	4		
SE	46	4	18	13	6	2
SSE	78	5	28	19	14	1[illegible]
S	4[illegible]	4	19	1[illegible]	6	2
SSW	[illegible]	1	4	[illegible]		
SW						
WSW						
W						[illegible]
WNW						
NW						
NNW						
TOTAL	1[illegible]	19	[illegible]	[illegible]	27	[illegible]
PERIOD	4	7	10	13	16	19

TYPHOON WAVES POINT [illegible]

09 25 18 H 1/3 = 7. [illegible] M

NORTH CORRESPONDS TO THE AZIMUTH [illegible]

N						
NNE						
NE						
ENE	[illegible]					
E						
ESE	1					
SE	[illegible]	1		6	8	4
SSE	49	[illegible]	34	36	1	
S	15[illegible]	2	34	[illegible]	[illegible]	[illegible]
SSW	34		[illegible]	[illegible]	[illegible]	
SW						
WSW						
W						
WNW						
NW						
NNW						
TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PERIOD	4	7	10	13	16	19

TYPHOON [illegible] POINT 1[illegible]

09 25 18 H 1/3 = [illegible]

NORTH CORRESPONDS TO THE AZIMUTH [illegible]

N through NNW	[illegible]	[illegible]
TOTAL	[illegible]	[illegible]
PERIOD	4 7 10 13 16 19	

TYPHOON WAVES POINT [illegible]

09 26 06 H 1/3 = [illegible]

NORTH CORRESPONDS TO THE AZIMUTH [illegible]

N through NNW	[illegible]	[illegible]
TOTAL	3[illegible]	[illegible]
PERIOD	4 7 10 13 16 19	

TYPHOON [illegible] POINT [illegible]

09 26 06 H 1/3 = [illegible]

NORTH CORRESPONDS TO THE AZIMUTH [illegible]

N through NNW	[illegible]	[illegible]
TOTAL	[illegible]	[illegible]
PERIOD	4 7 10 13 16 19	

TYPHOON WAVES POINT 4

H1/10 = 1[illegible].1 M

09 26 18

NORTH CORRESPONDS TO THE AZIMUTH 3[illegible]

N	0	•	0	0	[illegible]	[illegible]	0	0
NNE	0	•	0	0	0	0	0	0
NE	0	•	0	0	[illegible]	[illegible]	0	0
ENE	0	•	0	0	[illegible]	[illegible]	0	0
E	4	•	0	0	0	[illegible]	0	2
ESE	19	•	0	0	1	13	5	0
SE	145	•	0	0	25	53	25	41
SSE	[illegible]	•	0	0	32	54	48	53
S	192	•	0	0	25	55	44	46
SSW	79	•	0	0	9	6	15	48
SW	15	•	0	0	[illegible]	0	3	12
WSW	0	•	0	0	0	0	0	0
W	0	•	0	0	0	0	0	0
WNW	0	•	0	0	0	0	0	0
NW	0	•	0	0	0	[illegible]	0	0
NNW	0	•	0	0	0	0	0	0
TOTAL	645		0	0	44	143	162	2[illegible]4
PERIODS			4	7	10	13	16	19

TYPHOON POINT 12

H1/10 = 8.[illegible] M

09 26 18

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	•	0	0	0	0	0	0
NNE	0	•	0	0	0	0	0	0
NE	0	•	0	0	0	0	0	0
ENE	0	•	0	0	0	0	0	0
E	0	•	0	0	0	0	0	0
ESE	0	•	0	0	0	0	0	0
SE	57	•	0	0	9	15	17	15
SSE	194	•	0	1	20	56	57	59
S	146	•	0	0	19	60	57	49
SSW	26	•	0	0	4	3	0	18
SW	0	•	0	0	0	0	0	0
WSW	0	•	0	0	0	0	0	0
W	0	•	0	0	0	0	0	0
WNW	0	•	0	0	0	0	0	0
NW	0	•	0	0	0	0	0	0
NNW	0	•	0	0	0	0	0	0
TOTAL	465		0	2	53	136	131	141
PERIODS			4	7	10	13	16	19

TYPHOON WAVES POINT [illegible]

H1/3 = 4.[illegible] M

09 27 06

NORTH CORRESPONDS TO THE AZIMUTH [illegible]

N		•						
NNE		•						
NE		•						
ENE	[illegible]	•						
E		•						
ESE	[illegible]	•					2	
SE	[illegible]1	•			11	15	9	14
SSE	[illegible]	•			17	54	41	56
S	13[illegible]	•			2[illegible]	55	78	32
SSW	[illegible]	•			8	35	16	49
SW	23	•			7	3		12
WSW	[illegible]	•				[illegible]	1	
W		•						
WNW		•						
NW		•						
NNW		•						
TOTAL	[illegible]				7[illegible]	164	138	163
PERIODS			4	7	1[illegible]	13	16	19

TYPHOON POINT 12

H1/3 = 8.[illegible] M

09 27 06

NORTH CORRESPONDS TO THE AZIMUTH 76

N		•						
NNE		•						
NE		•						
ENE		•						
E		•						
ESE		•						
SE	37	•	[illegible]	1	9	11	7	8
SSE	144	•		0	17	51	22	51
S	2[illegible]2	•		0	7	54	72	54
SSW	42	•			6	25	1	8
SW		•						
WSW		•					1	0
W		•						0
WNW		•						
NW		•						
NNW		•						0
TOTAL	429			3	53	143	104	123
PERIODS			4	7	1[illegible]	13	16	19

TYPHOON WAVES POINT [illegible]

H1/3 = 3.7 M

09 27 18

NORTH CORRESPONDS TO THE AZIMUTH [illegible]

N		•						
NNE		•						
NE	1	•						1
ENE		•						
E	7	•			3	2		
ESE	59	•			15	3[illegible]	3	9
SE	2[illegible]1	•			25	57	41	35
SSE	19[illegible]	•		1	3[illegible]	58	49	59
S	128	•			16	39	34	28
SSW	8	•		9	4	2		2
SW	1	•			1			9
WSW		•						
W		•						
WNW		•						
NW		•						
NNW		•						
TOTAL	698			4	94	189	169	134
PERIODS			4	7	1[illegible]	13	16	19

TYPHOON WAVES POINT 6

H1/3 = 7.4 M

09 27 18

NORTH CORRESPONDS TO THE AZIMUTH 76

N		•						
NNE		•						
NE		•						
ENE	1	•						
E	67	•		1	1[illegible]	[illegible]	2	11
ESE	18[illegible]	•		1	26	57	63	31
SE	123	•		1	18	79	32	3[illegible]
SSE	14	•			4	9		
S		•						
SSW		•						
SW		•						
WSW		•						
W		•						
WNW		•						
NW		•						
NNW		•						
TOTAL	387			4	62	1[illegible]9	117	74
PERIODS			4	7	10	13	16	19

(OWEN)

TYPHOON WAVES POINT 6

H.1/10= 7.8 M

092718

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	•	0	0	0	0	0	0
NNE	0	•	0	0	0	0	0	0
NE	0	•	0	0	0	0	0	0
ENE	1	•	0	0	0	1	0	0
E	67	•	0	1	13	20	20	11
ESE	180	•	0	1	26	57	63	31
SE	121	•	0	1	18	39	32	30
SSE	14	•	0	0	4	9	0	0
S	0	•	0	0	0	0	0	0
SSW	0	•	0	0	0	0	0	0
SW	0	•	0	0	0	0	0	0
WSW	0	•	0	0	0	0	0	0
W	0	•	0	0	0	0	0	0
WNW	0	•	0	0	0	0	0	0
NW	0	•	0	0	0	0	0	0
NNW	0	•	0	0	0	0	0	0
TOTAL	387		0	4	62	120	117	74
	PERIODS		4	7	10	13	16	19

TYPHOON POINT 12

H.1/10= 7.7 M

092718

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	•	0	0	0	0	0	0
NNE	0	•	0	0	0	0	0	0
NE	0	•	0	0	0	0	0	0
ENE	0	•	0	0	0	0	0	0
E	0	•	0	0	0	0	0	0
ESE	2	•	0	0	0	2	0	0
SE	75	•	0	0	15	18	23	17
SSE	157	•	0	0	22	41	59	32
S	136	•	0	0	17	40	38	39
SSW	6	•	0	0	1	2	0	2
SW	0	•	0	0	0	0	0	0
WSW	0	•	0	0	0	0	0	0
W	0	•	0	0	0	0	0	0
WNW	0	•	0	0	0	0	1	0
NW	0	•	0	0	0	0	0	0
NNW	0	•	0	0	0	0	0	0
TOTAL	379		0	3	56	1[illegible]5	121	92
	PERIODS		4	7	10	13	16	19

TYPHOON WAVES POINT 4

H.1/10= 8.2 M

092806

NORTH CORRESPONDS TO THE AZIMUTH 360

N	0	•	0	0	0	0	0	0
NNE	0	•	0	0	0	0	0	0
NE	1	•	0	0	0	1	0	0
ENE	3	•	0	0	0	3	0	0
E	19	•	0	0	0	8	1[illegible]	0
ESE	60	•	0	0	15	13	31	0
SE	161	•	0	1	26	44	52	36
SSE	111	•	0	0	29	33	42	5
S	52	•	0	0	9	25	17	0
SSW	8	•	0	0	0	8	0	0
SW	3	•	0	0	0	3	0	0
WSW	0	•	0	0	0	0	0	0
W	0	•	0	0	0	0	0	0
WNW	0	•	0	0	0	0	0	0
NW	0	•	0	0	0	0	0	0
NNW	0	•	0	0	0	0	0	0
TOTAL	421		0	2	82	141	153	41
	PERIODS		4	7	13	13	16	19

TYPHOON POINT 12

H.1/1[illegible]= [illegible] M

092806

NORTH CORRESPONDS TO THE AZIMUTH 36[illegible]

N	0	•	0	0	0	0	0	0
NNE	0	•	0	0	0	0	0	0
NE	0	•	0	0	0	0	0	0
ENE	0	•	0	0	0	0	0	0
E	3	•	0	0	0	0	0	0
ESE	7	•	0	0	4	2	0	0
SE	91	•	0	1	15	25	24	14
SSE	184	•	0	1	25	52	64	45
S	121	•	0	1	18	34	4[illegible]	23
SSW	8	•	0	0	0	8		0
SW	0	•	0	0	0	0	0	0
WSW	0	•	0	0	0	0	0	0
W	0	•	0	0	0	0	0	0
WNW	0	•	0	0	0	0	0	0
NW	0	•	0	0	0	0	0	0
NNW	0	•	0	0	0	0	0	0
TOTAL	4[illegible]9		0	4	62	127	129	83
	PERIODS		4	7	10	13	16	19

TYPHOON WAVES POINT 4

H.1/10= 6.8 M

092818

NORTH CORRESPONDS TO THE AZIMUTH 36[illegible]

N	0	•	0	0		0	0	0
NNE	0	•	0	0		0	0	0
NE	0	•	0	0		0	0	0
ENE	0	•	0	0	0	0	0	0
E	0	•	0	0	0	0	0	0
ESE	2	•	0	0	2	0	0	0
SE	49	•	0	1	1	15	16	5
SSE	9[illegible]	•	0	8	29	17	17	17
S	122	•	0	6	32	27	26	29
SSW	15	•	0	0	15	0	0	0
SW	13	•	0	6	1	0	0	5
WSW	0	•	0	0	0	0	0	0
W	0	•	0	0		0	0	0
WNW	0	•	0	0		0	0	0
NW	0	•	0	0		0	0	0
NNW	0	•	0	0	0	0	0	0
TOTAL	294		0	23	92	[illegible]	[illegible]	5[illegible]
	PERIODS		4	7	10	13	16	19

TYPHOON WAVES POINT 4

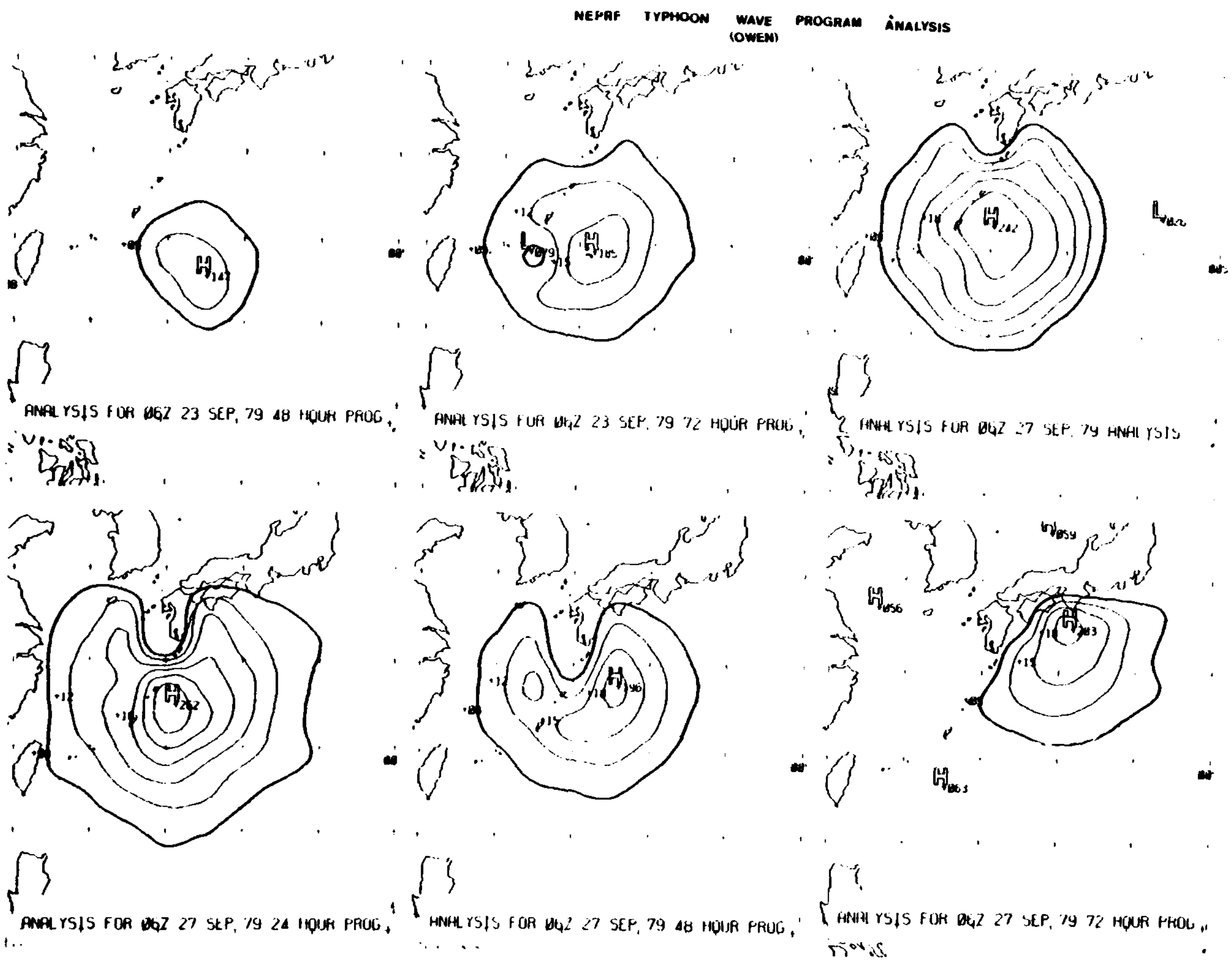
H.1/10= 7.5 M

092906

NORTH CORRESPONDS TO THE AZIMUTH 36[illegible]

N	0	•	0	0	0	0	0	0
NNE	0	•	0	0	0	0	0	0
NE	0	•	0	0	0	0	0	0
ENE	0	•	0	0	0	0	0	0
E	0	•	0	0	0	0	0	0
ESE	5	•	0	1	0	3	0	0
SE	55	•	0	2	11	18	12	11
SSE	1[illegible]8	•	0	3	38	32	15	17
S	120	•	0	4	31	41	28	15
SSW	69	•	0	1	14	0	8	44
SW	0	•	0	0		0	0	0
WSW	0	•	0	0	0	0	0	0
W	0	•	0	0	0	0	0	0
WNW	0	•	0	0	0	0	0	0
NW	0	•	0	0	0	0	0	0
NNW	0	•	0	0	0	0	0	0
TOTAL	358		0	13	94	96	63	90
	PERIODS		4	7	10	13	16	19

C-2. NEPRF Typhoon Wave Program Analysis (Owen)



ANALYSIS FOR 06Z 27 SEP 79 12 HOUR PROG

APPENDIX C

Propagation Energy Arrival Time

The following tables show the components from each source grid point, travel time and arrival time (GMT). R_o and R are determined from Map 1 (U.S. Navigation Chart No. 94027, Scale 1: 927.700 at lat $32^{o}15'$) from the critical depth of each period.

		Cgo/Cgs	10.6	15.2	18.7/29.4	24.3/33.6	28.8/35.8
		$\bar{T}$	7	10	13	16	19
12 Jul 30 (GMT)	PT4 17.4-133.9	Ro/R	1036	1036	896/140	873/163	866/170
		t	97.74	68.16	52.67	40.78	34.82
		tar	031344	0202809	011640	010447	312249
	PT12 17.4-135.3	Ro/R	1071	1071	941/130	876/175	884/187
		t	101.03	70.46	54.74	42.08	35.91
		tar	031702	021028	011844	010605	312355
00 Jul 31	PT4 18.6-131.5	Ro/R	919	919	749/170	719/200	709/210
		t	86.70	60.46	45.83	34.94	30.49
		tar	031443	021228	012150	011056	010629
	PT12 18.6-132.9	Ro/R	946	946	816/130	781/165	770/176
		t	89.29	62.24	48.06	37.05	31.66
		tar	031717	021414	020004	011303	010740
12 Jul 31	PT4 19.6-128.3	Ro/R	822	822	610/212	555/267	550/272
		t	77.55	54.08	39.83	30.79	26.70
		tar	031731	021847	020350	011847	011442
00 Aug 01	PT4 20.6-125.3	Ro/R	780	780	410/370	370/440	365/415
		t	73.56	51.32	34.52	27.43	24.26
		tar	040134	030319	021031	020326	020014
	PT12 20.6-126.8	Ro/R	756	756	501/255	476/280	471/285
		t	71.32	49.74	35.46	27.92	24.31
		tar	032319	030144	021128	020355	020019
12 Aug 01	PT4 21.5-122.2	Ro/R	744	744	324/420	284/460	279/465
		t	70.19	48.95	31.62	25.38	22.68
		tar	041011	031257	021937	021323	021041
	PT8 19.5-122.2	Ro/R	858	858	446/412	408/450	406/452
		t	80.94	56.45	37.86	30.18	26.73
		tar	042059	032027	030152	021811	021444
12 Aug 01	PT12 21.5-123.7	Ro/R	720	720	350/370	305/415	300/420
		t	67.92	47.37	31.30	24.90	22.15
		tar	040755	031122	021918	021254	021009
00 Aug 13	PT4 20.0-128.8	Cgo/Cgs	10.6/-	15.2/-	18.7/29.4	24.3/33.6	28.8/35.8
		Ro/R	802/-	802/-	562/240	550/252	546/256
		t	75.66	6.76	38.22	30.13	26.11
		tar	160340	150446	141413	140608	140207
	PT12 20.0-130.2	Ro/R	817/-	817/-	617/200	607/210	600/217
		t	77.08	53.75	39.80	31.23	26.89
		tar	160505	150545	141548	140714	140253

12 Aug 13	PT4	Ro/R	678/-	678/-	433/245	423/255	413/265
	22.0-138.2	t	63.96	44.61	31.49	25.00	21.74
		tar	160358	150837	141929	141300	140945
	PT12	Ro/R	692/-	692/-	467/225	452/240	442/250
	22.0-129.6	t	65.28	45.53	32.63	25.74	22.33
		tar	160519	150932	142038	141345	141020
00 Aug 14	PT4	Ro/R	583/-	583/-	323/260	303/280	300/283
	23.5-127.2	t	55.00	38.36	26.12	20.80	18.32
		tar	160700	151422	150207	142048	141819
	PT12	Ro/R	592/-	592/-	362/230	352/240	350/242
	23.5-128.6	t	55.85	38.95	27.18	21.63	18.91
		tar	160751	151457	150311	142138	141855
12 Aug 14	PT4	Ro/R	516/-	516/-	239/277	196/320	191/325
	24.6-126.7	t	48.68	33.95	22.20	17.59	15.71
		tar	161241	152157	151012	150535	150343
12 Aug 14	PT12	Ro/R	523/-	523/-	288/235	278/245	263/260
	24.6-128.2	t	49.34	34.41	23.39	18.73	16.39
		tar	161320	152224	151123	150614	150424
00 Aug 15	PT4	Ro/R	438/-	438/-	155/293	108/330	103/335
	25.9-126.5	t	41.32	28.82	18.25	14.27	12.93
		tar	161719	160449	151815	151416	151256
00 Aug 15	PT12	Ro/R	444/-	444/-	214/230	204/240	199/245
	25.9-128.0	t	41.89	29.10	19.27	15.53	13.75
		tar	161753	160513	151916	151532	151345
12 Aug 15	PT4	Ro/R	343/-	343/-	13/330	-/343	-/343
	27.5-126.0	t	32.36	22.57	11.92	10.21	9.58
		tar	162022	161034	152355	152213	152135
	PT8	Ro/R	464/-	464/-	144/320	119/345	109/355
	25.5-125.9	t	43.73	30.53	18.58	15.16	13.70
		tar	170744	161832	160635	160310	160142
	PT12	Ro/R	345/-	345/-	105/240	95/250	85/260
	27.5-127.5	t	32.54	22.70	13.78	11.35	10.21
		tar	162033	161042	160147	152321	152213
00 Aug 16	PT4	Ro/R	218/-	218/-	-/218	-/218	-/218
	29.6-126.0	t	20.57	14.34	7.41	6.49	6.09
		tar	162034	161421	160725	160629	160605
	PT8	Ro/R	337/-	337/-	20/317	-/317	-/317
	27.6-126.	t	31.79	22.17	11.85	10.03	9.41
		tar	170747	162210	161151	161002	160925

	PT12 29.6-127.5	Ro/R t tar	221/- 20.85 162051	221/- 14.54 161432	-/221 7.52 160731	-/221 6.58 160635	-/221 6.17 160610
06 Sep 25	PT4 21.3-132.4	Cgo/Cgs Ro/R t tar	10.6 784 73.96 280758	15.2 784 51.58 270935	18.0/29.4 654/730 39.39 262123	24.3/33.6 621/163 30.44 261225	28.8/35.8 611/173 26.05 260803
	PT12 21.3-133.9	Ro/R t tar	822 77.55 281133	822 54.08 271205	702/120 41.62 262337	662/160 32.00 261400	658/164 27.43 260926
18 Sep 25	PT4 22.6-131.7	Ro/R t tar	696 65.66 281140	696 45.73 271547	563/133 74.63 270438	513/183 26.56 262034	508/188 22.89 261653
	PT12 22.6-133.1	Ro/R t tar	731 68.96 281458	731 48.09 271805	610/121 36.74 270644	577/154 28.32 262219	574/157 24.32 261819
06 Sep 26	PT4 23.5-131.4	Ro/R t tar	639 60.28 281817	639 42.04 280002	509/130 31.64 271338	469/170 24.36 270622	419/220 20.07 270204
	PT12 23.5-132.8	Ro/R t tar	675 63.68 282141	675 44.41 280225	555/120 33.76 271546	522/153 26.03 270802	515/160 22.35 270421
18 Sep 26	PT4 24.4-131.6	Ro/R t tar	542 51.13 282108	542 35.66 280539	417/125 26.55 272034	382/160 20.48 271429	371/171 17.66 271140
	PT12 24.4-135.3	Ro/R t tar	667 62.92 290855	667 43.88 281353	607/60 34.5 280430	562/.05 26.26 272016	562/105 22.44 271626
06 Sep 27	PT4 25.5-131.9	Ro/R t tar	544 51.32 290919	544 35.79 281747	484/60 27.92 280955	410/134 20.86 280252	407/137 17.96 272358
	PT12 25.5-133.4	Ro/R t tar	591 55.75 291345	591 38.88 282053	526/65 30.34 281220	446/145 22.67 280440	443/148 19.52 280131
18 Sep 27	PT4 26.5-132.0	Ro/R t tar	496 46.79 291648	496 32.63 290238	430/66 25.24 281914	348/148 18.73 281244	345/151 16.20 281012

	PT6 28.5-132.1	Ro/R t tar	406 38.30 290818	406 26.71 282043	306/100 19.76 281346	251/155 14.94 280857	245/160 13.01 280706
	PT12 26.5-133.5	Ro/R t tar	547 51.60 292136	547 35.99 290559	487/60 28.08 282205	417/130 21.03 281502	407/140 18.04 281202
06 Sep 28	PT4 27.3-132.1	Ro/R t tar	460 43.40 300124	460 30.26 291216	400.60 23.43 290526	318/142 17.31 282319	315/145 14.99 282059
	PT12 27.3-133.5	Ro/R t tar	511 48.21 300612	511 33.62 291537	414/97 25.44 290726	386/125 19.61 290136	381/130 16.86 282252
18 Sep 28	PT4 27.8-132.1	Ro/R t tar	436 41.13 301108	436 28.68 292241	371/65 22.05 291603	291/145 16.29 291017	289/147 14.14 290608
06 Sep 29	PT4 28.5-132.4	Ro/R t tar	416 39.25 302115	416 27.37 300922	361/55 21.18 300311	291/125 15.70 292142	288/128 13.58 291935

APPENDIX D

Shoaling of the Spectral Energy Components

For refraction factor computation at 00 GMT August 13 from Point 4 of Typhoon Irving, the critical water depth is 325 feet and the angle between the swell crest and the bottom contour of 325 ft depth is 40^{o}. Thus, with h/gT^2 and the Figure 2-19 [7], the refraction factors are derived like the following:

$\bar{T}$ (sec) =	7	10	13	16	19
$K_r(\frac{H}{H_o})$ =	1	1	1	0.98	0.963

In the same way, the other refraction factors are shown in shoaling computation, in the following tables:

1. Shoaling Computation
    a. Typhoon Hope
    b. Typhoon Irving
    c. Typhoon Owen
2. Shoaling Energy and Arrival Times
    a. Typhoon Hope
    b. Typhoon Irving
    c. Typhoon Owen

1. Shoaling Computation

		$\bar{T}$	7	10	13	16	19	E (2^6· kilo erg/cm^2)	H 1/10 (in meters)
		k_s	1	1	0.92	0.89	0.90		
a. Typhoon Hope									
12 Jul 30	PT4	k_r	1	1	1	0.989	0.972		
(GMT)	17.4-133.9	$(k_s k_r)^2$	1	1	0.8464	0.7748	0.7653	E	H 1/10
	h = 413	SSE_o	7	19	11	9	14	63	3.17
	$\alpha_o = 40^o$	SSE_s	7	19	9.3	7.0	10.7	53	2.91
	PT12	k_r	1	1	1	1	0.98		
	17.4-135.3	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.7779		
	h = 413	SSE_o	8	28	31	36	42	147	4.85
	$\alpha_o = 35^o$	SSE_s	8	28	26.2	28.5	32.7	123.4	4.44
00 Jul 31	PT4	k_r	1	1	1	0.984	0.962		
	18.6-131.5	$(k_s k_r)^2$	1	1	0.8464	0.7670	0.7496		
	h = 413	SSE_o	4	15	20	13	15	69	3.32
	$\alpha_o = 45^o$	SSE_s	4	15	16.9	10.0	11.2	57.1	3.02
	PT12	k_r	1	1	1	1	0.982		
	18.6-132.9	$(k_s k_r)^2$	1	1	0.8467	0.7921	0.7811		
	h = 431	SSE_o	3	37	43	19	19	123	4.44
	α_o = 35	SSE	3	37	36.4	15	14.8	106.2	4.12
12 Jul 31	PT4	K_r	1	1	1	0.984	0.962		
	19.6-128.3	$(k_s k_r)^2$	1	1	0.8464	0.767	0.75		
	n = 413	S_o	0	23	30	46	20	121	4.40
	$\alpha_o = 45^o$	S_s	0	23	25.4	35.3	15	98.7	3.97
00 Aug 01	PT4	k_r	1	1	0.935	0.875	0.825		
	20.6-123.2	$(k_s k_r)^2$	1	1	0.7399	0.6065	0.5513		
	h = 236	SSW_o	5	23	30	19	40	118	4.35
	$\alpha_o = 60^o$	SSW_s	5	23	22.2	11.5	22.1	83.8	3.66

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TEST OF THE APPLICATION OF THE TYWAVES MODEL TO PREDICTION OF S--ETC(U)
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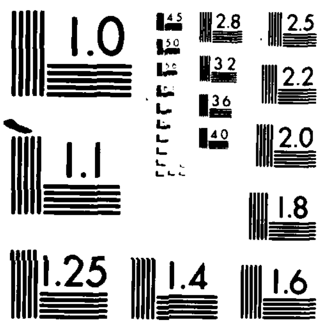

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

	PT12	k_r	1	1	1	1	0.98		
	20.6-126.8	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.7779		
	h = 413	S_o	0	20	71	98	52	243	6.24
	$\alpha_o = 35^o$	S_s	0	20	60.1	77.6	40.5	198.2	5.63
12 Aug 01	PT4	k_r	1	1	0.99	0.98	0.97		
	21.5-122.2	$(k_s k_r)^2$	1	1	0.8296	0.7607	0.7621		
	h = 236	SSW_o	0	11	33	3	10	58	3.05
	$\alpha_o = 30^o$	SSW_s	0	11	27.4	2.3	7.6	28.3	2.78
	PT8	k_r	1	1	0.97	0.93	0.88		
	19.5-122.2	$(k_s k_r)^2$	1	1	0.7963	0.6851	0.6272		
	h = 295	SSW_o	1	22	51	8	13	98	3.96
	$\alpha_o = 55^o$	SSW_s	1	22	40.6	5.5	8.2	77.3	3.52
	PT12	k_r	1	1	0.977	0.95	0.915		
	21.5-123.7	$(k_s k_r)^2$	1	1	0.8079	0.7149	0.6781		
	h = 295	SSW_o	0	6	17	49	31	104	4.08
	$\alpha_o = 50^o$	SSW_s	0	6	13.7	35.0	21	75.7	3.48

b. Typhoon Irving

00 Aug 13 (GMT)	PT4 20.0-128.8								
	deep	SSE	3	39	46	21	27	137	4.68m
	shoal	k_r	1	1	1	0.98	0.963		
	h = 325 ft	$(k_s k_r)^2$	1	1	0.8464	0.7607	0.7512		
	$\alpha_o = 40^o$	SSE	3	39	38.9	16.0	20.3	117.2	4.33

	PT12								
	20.0-130.2								
	deep	SSE	5	25	38	20	11	100	4.00
	shoal	k_r	1	1	1	1	1		
	h = 325	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
	α_o = 10	SSE	5	25	35.0	15.8	8.9	89.7	3.79
12 Aug 13	PT4								
	22.0-128.2								
	deep	SSE	4	30	31	25	13	105	4.10
	shoal	k_r	1	1	1	1	1		
	h = 325	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
	α_o = 10	SSE	4	30	26.2	19.8	10.5	90.5	3.81
	PT12								
	22.0-129.6								
	deep	SSE	3	24	20	15	4	67	3.27
	shoal	k_r	1	1	1	1	1		
	h = 325	$(k_s k_r)^2$	1	1	1	0.8464	0.7921	0.81	
	α_o = 10	SSE	3	24	16.9	11.9	3.2	59	3.07
00 Aug 14	PT4								
	23.5-125.0								
	deep	S	4	17	22	18	17	79	3.56
	shoal	k_r	1	1	1	0.97	0.95		
	h = 325	$(k_s k_r)^2$	1	1	0.8464	0.7453	0.7310		
	α_o = 4.5	S	4	17	18.6	13.4	12.4	65.4	3.23

	PT12								
	23.5-128.6								
	deep	SSE	4	30	30	28	20	114	4.27
	shoal	k_r	1	1	1	0.98	0.963		
	$h = 325$	$(k_s k_r)^2$	1	1	0.8464	0.7607	0.7512		
	$\alpha_o = 40$	SSE	4	30	25.4	21.3	15.0	95.7	3.91
12 Aug 14	PT4								
	24.6-126.7								
	deep	S	1	19	31	13	8	74	3.44
	shoal	k_r	1	1	0.975	0.94	0.91		
	$h = 266$	$(k_s k_r)^2$	1	1	0.8046	0.7	0.6708		
	$\alpha_o = 50$	S	1	19	24.9	9.1	5.4	59.4	3.08
	PT12								
	24.6-128.2								
	deep	SSE	1	28	33	34	27	125	4.47
	shoal	k_r	1	1	1	0.98	0.963		
	$h = 325$	$(k_s k_r)^2$	1	1	0.8464	0.7607	0.7512		
	$\alpha_o = 40$	SSE	1	28	27.9	25.9	20.3	103.1	4.06
00 Aug 15	PT4								
	25.9-126.5								
	deep	S	9	40	36	23	22	132	4.60
	shoal	k_r	1	1	0.99	0.976	0.948		
	$h = 266$	$(k_s k_r)^2$	1	1	0.8296	0.7545	0.728		
	$\alpha_o = 40$	S	9	40	29.9	17.4	16.0	112.3	4.24

	PT12								
	25.9-128.0								
	deep	SSE_o	3	29	20	17	40	110	4.20
	shoal	k_r	1	1	1	0.98	0.95		
	h = 325	$(k_s k_r)^2$	1	1	0.8464	0.7607	0.7310		
	α_o = 45	SSE_s	3	29	16.9	12.9	29.2	91.0	3.82
	"								
	deep	S	3	34	41	33	12	125	4.47
	shoal	k_r	1	1	1	0.985	0.96		
	h = 472	$(k_s k_r)^2$	1	1	0.8464	0.7685	0.7465		
	α_o = 50	S	3	34	34.7	25.4	9.0	106.1	4.12
12 Aug 15	PT4								
	27.5-126.0								
	deep	S	0	19	13	24	15	73	3.42
	shoal	k_r	1	1	0.983	0.957	0.93		
	h = 266	$(k_s k_r)^2$	1	1	0.8179	0.7254	0.7006		
	α_o = 45	S	0	19	10.6	17.4	10.5	57.5	3.03
	PT8								
	25.5-125.9								
	deep	S	1	17	15	14	13	62	3.15
	shoal	k_r	1	1	0.988	0.967	0.95		
	h = 261	$(k_s k_r)^2$	1	1	0.8262	0.7407	0.7310		
	α_o = 40	S	1	17	12.4	10.4	9.5	50.3	2.84

	PT12								
	29.5-127.5								
	deep	SSE	1	21	56	55	75	212	5.82
	shoal	k_r	1	1	1	0.97	0.95		
	h = 325	$(k_s k_r)^2$	1	1	0.8464	0.7353	0.7310		
	α_o = 45	SSE	1	1	47.4	41	54.8	145.2	4.82
	PT12								
	27.5-127.5								
	deep	S	0	17	38	50	43	153	4.95
	shoal	k_r	1	1	1	0.975	0.94		
	h = 384	$(k_s k_r)^2$	1	1	0.8464	0.7530	0.7157		
	α_o = 51	S	0	17	32.2	39.9	30.8	119.9	4.38
00 Aug 16	PT4								
	29.6-126.0								
	deep	S	0	15	14	19	15	65	3.22
	shoal	k_r	1	1	1	1	1		
	h = 266	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
	α_o = 0	S	1	15	11.8	15.0	12.2	54	2.94
	PT8								
	27.6-126.0								
	deep	S	0	16	20	31	21	90	3.79
	shoal	k_r	1	1	0.983	0.957	0.93		
	h = 266	$(k_s k_r)^2$	1	1	0.8179	0.7254	0.7006		
	α_o = 45	S	0	16	16.4	22.5	14.7	69.6	3.34

PT8								
27.6-126.0								
deep	SSW	0	33	62	47	31	175	5.29
shoal	k_r	1	1	0.976	0.93	0.87		
h = 325	$(k_s k_r)^2$	1	1	0.8063	0.6851	0.6131		
α_o = 60	SSW	0	33	50	32.2	19	134.2	4.63
PT12								
29.6-127.5								
deep	SSE	1	24	54	60	38	179	5.35
shoal	k_r	1	1	1	1	1		
h = 354	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
α_o = 15	SSE	1	24	45.7	47.5	30.8	149	4.88
PT12								
29.6-127.5								
deep	S	1	21	40	40	19	122	4.42
shoal	k_r	1	1	1	0.96	0.93		
h = 384	$(k_s k_r)^2$	1	1	0.8464	0.73	0.7001		
α_o = 50	S	1	21	33.9	29.2	13.3	98.4	3.97

c. Typhoon Owen

06 Sep 25 (GMT)	PT4	k_r	1	1	1	1	0.98		
	21.3-132.4	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.7779		
	h = 413 ft	$(SSE)_o$	7	26	31	8	0	74	3.44
	$\alpha_o = 35^o$	$(SSE)_s$	7	26	26.2	6.3	0	65.5	3.24
	PT12	k_r	1	1	1	1	0.98		
	21.3-133.9	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.7779		
	h = 413	SSE_o	5	28	19	14	10	78	3.53
	$\alpha_o = 35$	SSE_s	5	28	16.1	11.1	7.8	68	3.30
18 Sep 25	PT4	k_r	1	1	1	0.989	0.973		
	22.6-131.7	$(k_s k_r)^2$	1	1	0.8464	0.7335	0.7716		
	h = 413	SSE_o	3	38	36	10	0	89	3.77
	$\alpha_o = 40$	SSE_s	3	38	30.5	7.3	0	78.8	3.55
	PT12	k_r	1	1	1	1	0.985		
	22.6-133.1	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.7859		
	h = 413	SSE_o	2	27	34	15	9	88	3.75
	$\alpha_o = 30$	SSE_s	2	27	28.8	11.9	7.1	76.8	3.50
06 Sep 26	PT4	k_r	1	1	1	0.985	0.95		
	23.5-131.4	$(k_s k_r)^2$	1	1	0.8464	0.7685	0.73		
	h = 384	SSE_o	2	39	54	42	1	140	4.73
	$\alpha_o = 47$	SSE_s	2	39	45.7	32.3	0.7	119.7	4.38

	PT12	k_r	1	1	1	1	0.985		
	23.5-132.8	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.7859		
	h = 384	SSE_o	2	33	49	26	19	132	4.60
	$\alpha_o = 33$	SSE_s	2	33	41.5	20.6	14.9	112	4.23
18 Sep 26	PT4	k_r	1	1	1	1	0.983		
	24.4-131.6	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.0827		
	h = 384	SSE_o	0	32	54	48	53	188	5.48
	$\alpha_o = 35$	SSE_s	0	32	45.7	38	41.5	157.2	5.01
	PT12	k_r	1	1	1	1	1		
	24.4-135.3	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
	h = 431	SE_o	0	9	15	17	15		
	$\alpha_o < 10$	SE_s	0	9	12.7	13.5	12.2	47.4	2.75
06 Sep 27	PT4	k_r	1	1	1	1	1		
	25.5-131.9	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
	h = 354	SSE_o	0	17	54	31	56	150	4.90
	$\alpha_o < 10$	SSE_s	0	17	45.7	24.6	45.4	132.7	4.61
	PT12	k_r	1	1	1	1	1		
	25.5-133.4	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
	h = 413	SE_o	1	9	11	7	8	37	2.43
	$\alpha_o < 10$	SE_s	1	9	9.3	5.5	6.5	31.3	2.23

18 Sep 27	PT4	k_r	1	1	1	1	1		
	26.5-132.0	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
	h = 413	SSE_o	1	30	58	49	39	180	5.37
	α_o<10	SSE_s	1	30	49.1	38.8	31.6	150.5	4.91
	PT6	k_r	1	1	1	1	1		
	28.5-132.1	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
	h = 431	SE_o	1	18	39	32	30	123	4.44
	α_o<10	SE_s	1	18	33	25.3	24.3	101.6	4.03
	PT12	k_r	1	1	1	1	1		
	26.5-133.5	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
	h = 431	SE_o	0	15	18	23	17	75	3.46
	α_o<10	SE_s	0	15	15.2	18.2	13.8	62.2	3.15
	PT4	k_r	1	1	1	1	1		
	26.5-132.0	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
	h = 413	SE_o	0	26	57	81	35	201	5.67
	α_o<10	SE_s	0	26	48.2	64.2	28.4	166.8	5.17
06 Sep 28	PT4	k_r	1	1	1	1	1		
	27.3-132.1	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
	h = 431	SE_o	1	26	44	52	36	161	5.08
	α_o<0	SE_s	1	26	37.2	41.2	29.2	134.6	4.64

	PT12	k_r	1	1	1	1	1		
	27.3-133.5	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
	h = 431	SE_o	1	15	25	24	14	81	3.60
	α_o<10	SE_s	1	15	21.2	19	11.3	67.5	3.29
18 Sep 28	PT4	k_r	1	1	1	1	1		
	27.8-132.1	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
	h = 431	SE_o	1	10	15	16	5	49	2.80
	α_o<10	SE_s	1	10	12.7	12.7	4.0	40.4	2.54
06 Sep 29	PT4	k_r	1	1	1	1	1		
	28.5-132.4	$(k_s k_r)^2$	1	1	0.8464	0.7921	0.81		
	h = 431	SE_o	2	10	18	12	11	55	2.96
	α_o<10	SE_s	2	10	15.2	9.5	8.9	45.6	2.70

2. Shoaling Energy and Arrival Time

a. Typhoon Hope

		$\bar{T}$	7	10	13	16	19	SUM
12 Jul 30	PT4	t	97.74	68.16	52.67	40.78	34.82	
(GMT)		tar	031344	020809	011640	010447	312049	
	17.4-133.9	SSE_o	7	19	11	9	14	63
		SSE_s	7	19	9.3	7.0	10.7	53
	PT12	t	101.03	70.46	54.74	42.08	35.91	
		tar	031702	021028	011844	010605	312355	
	17.4-135.3	SSE_o	8	28	31	36	42	147
		SSE_s	8	28	26.2	28.5	32.7	123.4

00 Jul 31	PT4	t	86.72	60.46	45.83	34.94	30.48	
		tar	031443	021228	012150	011056	010629	
	18.6-131.5	SSE_o	4	15	20	13	15	69
		SSE_s	4	15	16.9	10.0	11.2	57.1
	PT12	t	89.29	62.24	48.06	37.05	31.66	
		tar	031717	021414	020004	011303	010740	
	18.6-132.9	SSE_o	3	37	43	19	19	123
		SSE_s	3	37	36.4	15	14.8	106.2
12 Jul 31	PT4	t	77.51	54.08	39.83	30.79	26.70	
		tar	031731	021847	020350	011847	011442	
	19.6-128.3	S_o	0	23	30	46	20	121
		S_s	0	23	25.4	35.3	15	78.7
00 Aug 01	PT4	t	73.56	57.32	34.52	27.43	24.26	
		tar	040134	030319	021031	020326	020014	
	20.6-132.2	SSW_o	5	23	30	19	40	118
		SSW_s	5	23	22.2	115	22.1	89.8
	PT8	t	71.32	49.74	35.46	27.92	24.31	
		tar	032319	030144	021128	020355	020019	
	20.6-126.8	S_o	0	20	71	98	52	243
		S_s	0	20	60.1	77.6	40.5	198.2
12 Aug 01	PT4	t	70.19	48.95	31.62	25.38	22.68	
		tar	041011	031257	021937	021323	021041	
	21.5-122.2	SSW_o	0	11	33	3	10	58
		SSW_s	0	11	27.4	2.3	7.6	48.3

PT8		t	80.98	56.45	37.86	30.18	26.73	
		tar	042059	032027	030152	021811	021444	
19.5-122.2		SSW_o	1	22	51	81	13	98
		SSW_s	1	22	40.6	5.5	8.2	77.3
PT12		t	67.92	47.37	31.30	24.90	22.15	
		tar	040755	031122	021918	021254	021009	
21.5-123.7		SSW_o	0	6	17	49	31	104
		SSW_s	0	6	13.7	35.0	21	75.7

b. Typhoon Irving

		$\bar{T}$	7	10	13	16	19	SUM
00 Aug 13	PT4	t	75.66	52.76	38.22	30.13	26.11	
		tar	160340	150446	141413	140608	140207	
	20.0-128.8	SSE_o	3	39	46	21	27	137
		SSE_s	3	39	38.9	16.0	20.3	117.2
	PT12	t	77.08	53.75	39.80	31.23	26.89	
		tar	160505	150545	141548	140714	140253	
	20.0-130.2	SSE_o	5	25	38	20	11	100
		SSE_s	5	25	35.0	15.8	8.9	89.7
12 Aug 13	PT4	t	63.96	44.61	31.49	25.00	21.74	
		tar	160358	150836	141929	141300	140945	
	22.0-128.2	SSE_o	4	30	31	25	13	105
		SSE_s	4	30	26.2	19.8	10.5	90.5
	PT12	t	65.28	45.53	32.63	25.74	22.33	
		tar	160517	150932	142038	141345	141020	
	22.0-129.6	SSE_o	3	24	20	15	4	67
		SSE_s	3	24	16.9	11.9	3.2	59

00 Aug 14	PT4		t	55.00	38.36	26.12	20.80	18.22	
			tar	160700	151422	150207	142048	141819	
		23.5-127.2	S_o	4	17	22	18	17	79
			S_s	4	17	18.6	13.4	12.4	65.4
	PT12		t	55.85	38.95	27.18	21.63	18.91	
			tar	160751	151457	150311	142138	141855	
		23.5-128.5	SSE_o	4	30	30	28	20	114
			SSE_s	4	30	25.4	21.3	15.0	95.7
12 Aug 14	PT4		t	48.68	33.95	22.20	17.59	15.71	
			tar	161241	152157	151012	150535	150343	
		24.6-126.7	S_o	1	19	31	13	8	74
			S_s	1	19	24.9	9.1	5.4	59.4
	PT12		t	49.34	34.41	23.39	18.73	16.39	
			tar	161320	152224	151123	150614	150424	
		24.6-128.2	SSE_o	1	28	33	34	27	125
			SSE_s	1	28	27.9	25.9	20.3	103.1
00 Aug 15	PT4		t	41.32	28.82	18.25	14.27	12.93	
			tar	161719	160449	151815	151416	151256	
		25.9-126.5	S_o	9	40	36	23	22	132
			S_s	9	40	29.9	17.4	16.0	112.3
	PT12		t	41.89	29.10	19.27	15.53	13.75	
			tar	161753	160513	151916	151532	151345	
		25.9-128.0	SSE_o	3	29	20	17	40	110
			SSE_s	3	29	16.9	12.9	29.2	91.0
	PT12		t	41.89	29.10	19.27	15.53	13.75	
			tar	161753	160513	151916	151532	151345	
		25.9-128.0	S_o	3	34	41	33	12	125
			S_s	3	34	34.7	25.4	9.0	106.1

12 Aug 15	PT4	t	32.36	22.57	11.92	10.21	9.58	
		tar	162022	161034	152355	152213	152135	
	27.5-126.0	S_o	0	19	13	24	15	73
		S_s	0	19	10.6	17.4	10.5	57.5
	PT8	t	43.73	30.53	18.58	15.16	13.70	
		tar	170744	161832	160635	160310	160142	
	25.5-125.9	S_o	1	17	15	14	13	62
		S_s	1	17	12.4	10.4	9.5	50.3
	PT12	t	32.54	22.70	13.78	11.35	10.21	
		tar	162033	161042	160147	152321	152231	
	27.5-127.5	SSE_o	1	21	56	55	75	212
		SSE_s	1	21	47.4	41	54.8	145.2
	PT12	t	32.54	22.70	13.78	11.35	10.21	
		tar	162033	161042	160147	152321	152231	
	27.5-127.5	S_o	0	17	38	53	43	153
		S_s	0	17	322	39.9	30.8	119.9
00 Aug 16	PT4	t	20.57	14.34	7.41	6.49	6.09	
		tar	162034	161421	160725	160629	160605	
	29.6-126.0	S_o	0	15	14	19	15	65
		S_s	0	15	11.8	15.0	12.2	54
	PT8	t	31.79	22.17	11.85	10.03	9.41	
		tar	170747	162210	161151	161002	160925	
	27.6-126.0	S_o	0	16	20	31	21	90
		S_s	0	16	16.4	22.5	14.7	69.6
	PT8	t	31.79	22.17	11.85	10.03	9.41	
		tar	170747	162210	161151	161002	160925	
	27.6-126.0	SSW_o	0	33	62	47	31	175
		SSW_s	0	33	50	32.2	19	134.2

	PT12	t	20.85	14.54	7.52	6.58	6.17	
		tar	162051	161432	160731	160635	160610	
	29.6-127.5	SSE_o	1	24	54	60	38	179
		SSE_s	1	24	45.7	47.5	30.8	149
	PT12	t	20.85	14.54	7.52	6.58	6.17	
		tar	162051	161432	160731	160635	160610	
	29.6-127.5	S_o	1	21	40	40	19	122
		S_s	1	21	33.9	29.2	13.3	98.4

c. Typhoon Owen

		$\bar{T}$	7	10	13	16	19	SUM
06 Sep 25 (GMT)	PT4	t	73.96	51.58	39.39	30.41	26.05	
		tar	280758	270935	262123	261225	260803	
	21.3-132.4	SSE_o	7	26	31	8	0	74
		SSE_s	7	26	26.2	6.3	0	65.5
	PT12	t	77.55	54.08	41.62	32.00	27.43	
		tar	281133	271205	262337	261400	260926	
	21.1-133.9	SSE_o	5	28	19	14	10	78
		SSE_s	5	28	16.1	11.1	7.8	68
18 Sep 25	PT4	t	65.66	45.79	34.63	26.56	22.89	
		tar	281140	271547	270438	262034	261653	
	22.6-131.7	SSE_o	3	38	36	10	0	89
		SSE_s	3	38	30.5	7.3	0	78.8
	PT12	t	68.96	48.09	36.74	28.32	24.32	
		tar	281458	271805	270644	262219	261819	
	22.6-133.1	SSE_o	2	27	34	15	9	88
		SSE_s	2	27	28.8	11.9	7.1	76.8

06 Sep 26	PT4		t	60.28	42.04	31.64	24.36	20.07	
			tar	281817	280002	241338	270622	270204	
		22.5-131.4	SSE_o	2	39	54	42	1	140
			SSE_s	2	39	45.7	32.3	0.7	119.7
	PT12		t	63.68	44.41	33.76	26.03	22.35	
			tar	282141	280225	271546	270802	270421	
		23.5-132.8	SSE_o	2	33	49	26	19	132
			SSE_s	2	33	41.5	20.6	14.9	112
18 Sep 26	PT4		t	51.13	35.66	26.55	20.48	17.66	
			tar	282108	280539	272034	271429	271140	
		24.4-131.6	SSE_o	0	32	54	48	53	188
			SSE_s	0	32	45.7	38	41.5	157.2
	PT12		t	62.92	43.88	34.5	26.26	22.44	
			tar	290855	281353	280430	272016	271626	
		29.4-135.3	SE_o	0	9	15	17	15	57
			SE_s	0	9	12.7	13.5	12.2	47.4
06 Sep 27	PT4		t	51.32	35.79	27.92	20.86	17.96	
			tar	290919	281747	280955	280252	272358	
		25.5-131.9	SSE_o	0	17	54	31	56	160
			SSE_s	0	17	45.7	24.6	45.4	132.7
	PT12		t	55.75	38.88	30.34	22.67	19.52	
			tar	291345	282053	281220	280440	280131	
		25.5-133.4	SE_o	1	9	11	7	8	37
			SE_s	1	9	93	5.5	6.5	31.3
18 Sep 27	PT4		t	46.79	32.63	25.24	18.73	16.20	
			tar	291648	290238	281914	281244	281012	
		26.5-132.0	SSE_o	1	30	58	49	39	180
			SSE_s	1	30	49.1	38.8	31.6	150.5

	PT4	t	46.79	32.63	25.24	18.73	16.20	
		tar	291648	290238	281914	281244	281012	
	26.5-132.0	SE_O	0	26	57	81	35	201
		SE_S	0	26	48.2	64.2	28.4	166.8
	PT6	t	38.30	26.71	19.76	14.94	13.01	
		tar	290818	282043	281346	280857	280706	
	28.5-132.1	SE_O	1	18	39	32	30	123
		SE_S	1	18	33	25.3	24.3	101.6
	PT12	t	51.60	35.99	28.08	21.03	18.04	
		tar	292136	290559	280205	281502	281202	
	26.5-133.5	SE_O	0	15	18	23	17	75
		SE_S	0	15	15.2	18.2	13.8	62.2
06 Sep 28	PT4	t	43.40	30.26	23.43	17.31	14.99	
		tar	300124	291216	290526	282319	282059	
	27.3-132.1	SE_O	1	26	44	52	36	161
		SE_S	1	26	37.2	41.2	29.2	134.6
	PT12	t	48.21	33.62	25.44	19.61	16.86	
		tar	300612	291537	290726	290136	282252	
	27.3-133.5	SE_O	1	15	25	24	14	81
		SE_S	1	15	21.2	19	11.3	67.5
18 Sep 28	PT4	t	41.13	28.68	22.05	16.29	14.14	
		tar	301108	292241	291603	291017	290608	
	27.8-132.1	SE_O	1	10	15	16	5	49
		SE_S	1	10	12.7	12.7	4.0	40.4
06 Sep 29	PT4	t	39.25	27.37	21.18	15.70	13.58	
		tar	302115	300922	300311	292142	291935	
	28.5-132.4	SE_O	2	10	18	12	11	55
		SE_S	2	10	15.2	9.5	8.9	45.6

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